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THE ROYAL SOCIETY
EMPIRE SCIENTIFIC CONFERENCE

VOL. I

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ROYAL SOCIETY
EMPIRE SCIENTIFIC
CONFERENCE

JUNE–JULY
1946

Report

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(OF TWO VOLUMES)

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J. D. Griffith Davies, O.B.E., Assistant Secretary, the Royal Society.

I. Kaye, Editor for the Conference, the Royal Society.

R. Terrell, Editor for the Conference, the Royal Society.

T. S. Chegwidden, C.B., C.V.O., H.M. Treasury.

F. P. Bowden, Department of Physical Chemistry, Cambridge University.

G. F. Hickson, Board of Extra Mural Studies, Cambridge University.

T. W. J. Taylor, C.B.E., Brasenose College, Oxford University.

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Professor E. J. HARTUNG
Professor E. SHERBON HILLS
Sir JOHN MADSEN
Mr H. R. MARSTON
Sir DAVID RIVETT, F.R.S.
Dr H. C. TRUMBLE

BURMA

Mr M. V. EDWARDS
Mr F. D. ODELL

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Mr J. H. PARKIN
Dr J. K. ROBERTSON

CEYLON

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Mr A. GLENDON HILL
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Professor E. T. S. WALTON

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Professor S. F. OOSTHUIZEN
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Dr J. C. HOPKINS
Major B. LIGHTFOOT
Mr C. L. ROBERTSON

TRINIDAD

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Professor P. M. S. BLACKETT, F.R.S.
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Professor C. E. TILLEY, F.R.S.
Sir HENRY TIZARD, F.R.S.

WEST INDIES

Dr SMITH BRACEWELL
Dr H. H. BROWN
Mr R. JOHNS
Mr A. J. WAKEFIELD

INTRODUCTION

I. The origin of the conference

The proposal to hold an Empire Scientific Conference arose from discussions initiated at the Royal Society with the Secretaries, Professor A. V. Hill and Sir Alfred Egerton, by Dr Alexander King, then of the Ministry of Supply and later head of the United Kingdom Scientific Mission of the British Commonwealth Scientific Office in Washington, and Mr Neville Wright then of the New Zealand Office in London.

The next step was a Conference called by the Officers of the Royal Society on 7 October 1941. This was attended by representatives of Canada, Australia, New Zealand, South Africa and India, the Secretaries of the Research Councils and of the Royal Society, Lord Hankey and Dr Alexander King. A Committee, entitled the British Commonwealth Science Committee, under the chairmanship of Sir Henry Dale, then President of the Royal Society, was set up with Dr Alexander King as secretary. The report of this Committee was printed and presented to the Council of the Royal Society in early April 1943. Preliminary and useful discussions in Australia and Canada with Sir Henry Tizard and exchanges of views with the other Dominions were also held during 1943.

The Report, which suggested that an Empire Scientific Conference be convened as soon as possible after the war, was sent to the Scientific Advisory Committee of the War Cabinet. In July 1944 His Majesty's Government in the United Kingdom informed the Royal Society of their approval of the proposal and invited them to be responsible for the organization of the Conference. At the meeting of the Royal Society on 8 August 1944 it was agreed that the Conference should be held in London and that it should consist of scientists as such rather than officials. The Royal Society accordingly entered into correspondence with the High Commissioners of the Dominions in London regarding arrangements for convening the Conference and about the same time the United Kingdom Government proposed to the other Governments of the Commonwealth that an Official Scientific Conference should be convened in close association with the Royal Society's Conference.

In January 1945 it was arranged with the Treasury that the sum of £15,000 to cover the expenses of the Conference should be included in the Estimates.

A Policy Committee for the Conference held its first meeting in February 1945. Sir Alfred Egerton was the Chairman and the Committee included the Secretaries of the Department of Scientific and Industrial Research, the Agricultural Research Council, the Medical Research Council and the senior representative of the Dominions Office. The Colonial Office and the Dominions were, throughout, kept in touch with all the arrangements. The date, the period, and the size of the delegations were settled by exchange of views with the Dominions, India and the Colonial Office.

Although the outcome of the Japanese war could not be foreseen, the date of the Conference was, nevertheless, provisionally arranged for June 1946, to last five weeks (three for the Royal Society Conference and two for the British Commonwealth Official Scientific Conference which was to follow).

It became clear that the functions of the two conferences would be complementary. In the free atmosphere of the Royal Society Conference there would be an opportunity for delegates to express their views as individuals, without committing any governments or departments. At the Official Conference the delegates would be able to sit down to detailed consideration of proposals with a clear conception of the personal attitudes of their fellows who would have expressed themselves with some candour at the Royal Society Conference. This relation between the two conferences was not lost sight of at any time and much credit for the success of both is due to the foresight of those who originated the scheme. The Working Party preparing for the Official Conference under the chairmanship of Mr O. F. Brown of the Department of Scientific and Industrial Research kept in close touch with the Royal Society's Policy Committee.

In October 1945 the Treasury made available the services of Mr T. S. Chegwidden to assist in the planning work of the Policy Committee. At the end of the year Sir Henry Tizard became the Chairman of the Committee. He and Sir Alfred Egerton actually shared the chairmanship until the last few meetings, for which the President, Sir Robert Robinson, was responsible.

The actual programme for the Conference was first drafted in November 1945 and circulated to the Dominions for the comments of leading men of science in those countries and in the United Kingdom. Indeed, the views of a great many Fellows of the Royal Society and of others in many parts of the Empire were invited as to the scope of the agenda before it was finally settled only two or three months before the Conference began. The composition of the delegations from the countries of the Commonwealth was decided in the countries themselves, the British team alone being selected by the Council of the Royal Society. In addition to the delegates some two hundred scientists in this country were invited to participate in particular discussions. The difficulties of accommodation and food restrictions placed strict limits on the numbers so that it was not possible to invite as many delegates from abroad as one could have wished.

II. The conduct of the discussions

This report gives a brief account of each of the morning discussions at the Conference, together with the recommendations adopted at the final session. A list of papers presented by delegates and others is included. The report also contains such recommendations as emerged from certain of the informal discussions that were held in the evenings.

The morning discussions were planned in such a way as to make possible a coherent presentation of each particular set of problems, having regard to the difficulties in organizing the Conference itself. Among such difficulties were the following :

Firstly, the subjects were framed very broadly and the contributors of papers from different parts of the Commonwealth were free to adopt widely varying standpoints with regard to them. Only three hours were allotted for the discussion of each subject and for some months before the start of the Conference it was not easy to see how justice could be done to the many papers that were coming in.

Secondly, the delegation of scientists from each country tended to think as a team about its own special problems and a means had to be devised for giving due weight in each discussion to the special point of view of each team.

Thirdly, owing to the shortage of manpower and other difficulties in the printing industry, it was not found possible to enable most delegates to see any of the papers submitted by scientists from countries other than their own before the start of the Conference. It was not possible, therefore, to discuss papers in any detail and delegates were obliged to address their audiences on the assumption that papers had not actually been read by more than a small minority.

The plan adopted for the discussions was as follows :

About one month before the Conference the Royal Society invited two scientists in the United Kingdom in each of the fields covered by the forthcoming discussions to act as the ' leader ' and ' recorder ' for each morning session. These persons kindly undertook to read all the papers on their particular subjects as soon as they were made available from the printer. They made it their business to consider the various views expressed in the papers and to make tentative plans for the discussions. The leaders and recorders were invited to be the representatives of the United Kingdom team on the steering groups set up for the discussions. Each group consisted of seven or eight persons chosen to represent particular fields of science and the various countries of the Commonwealth. One representative of the Colonies taken as a whole was a member of each steering group. Thus, the steering group for the discussion on the need for a co-ordinated survey of the mineral resources of the Empire consisted mainly of geologists and mineralogists from the various countries, that for the discussion of agricultural problems consisted of agricultural scientists and development officers, and so on. Altogether fourteen such groups were set up and each performed its duty with remarkable smoothness and efficiency.

Each group met, as a rule, the day before the discussion in question and also very shortly after it. At the first meeting the leader or the recorder explained the general contents of the papers that had been presented and suggested the way the discussion should be planned. Sometimes the plan would provide for a series of reviews of the problem given by a speaker from each country. Sometimes the subject lent itself better to a systematic approach, dealing with various aspects, irrespective of the countries represented at the Conference. Each group, assisted by the leader and recorder, made its own plan, elected its own chairman for the discussion and generally solved its problems in its own way. At the first meeting the group decided how many set speeches should be delivered, the order of speakers, and the time to be made available for general discussion.

At the discussions themselves recommendations were not put to the vote, any such procedure being impracticable. The chairman, as a rule, outlined the plan for the discussion, after which speakers were invited to make statements of from five to twenty minutes' duration. General discussion followed and occasionally some debate.

At the meetings after the discussions the steering groups discussed the most acceptable form in which recommendations of the Conference might

be expressed. The drafting was normally the work of the recorders assisted by the other members of the steering groups. In drafting the recommendations the groups made it their business to express the feelings of the delegates and guests present at the discussions.

The reports and recommendations of the steering groups were posted prominently in the premises occupied by the Conference and delegates wishing to make amendments were invited to communicate them to the chairmen of the group dealing with the subject. A number of such amendments was collected.

The Steering Committee for the Conference, consisting of the President and Officers of the Royal Society, together with the leaders of the delegations from Commonwealth countries, met on four occasions before and during the period of the Conference, to consider and co-ordinate the recommendations submitted by the various steering groups. The Steering Committee made a number of amendments which usually represented an agreed compromise between the leaders of delegations designed to meet differences of opinion as to special recommendations. At its final meeting on the evening of 6 July, the Steering Committee agreed to the form in which the recommendations of the steering groups should be presented to the final session of the Conference on the morning of 8 July.

The Committee also considered a proposal for the setting up of a permanent committee consisting of the leaders of the Conference delegations under the auspices of the Royal Society for the purpose of following up the Conference in future years. The proposals were left in a tentative form by the Steering Committee but the Official Conference accepted the proposal in principle and set up a Standing Committee consisting of the executive heads of Government Scientific organizations in the United Kingdom, the Dominions and India and representatives of the Colonial Office, and with a Working Party in London composed of their deputies to further the objects of the Official Conference to facilitate action on its recommendations.

At the final session the Conference considered and accepted a few further amendments, moved from the floor, after these had been put to the vote by a show of hands. The recommendations as they appear in this report represent the agreed views of the final meeting of delegates to the Conference.

RECOMMENDATION ADOPTED BY THE CONFERENCE AT THE FINAL SESSION, 8 JULY

That the Council of the Royal Society be requested to prepare a considered report on the Proceedings of the Conference. Such a report should include recommendations of measures designed to promote the advance of science in the nations of the Commonwealth, to facilitate co-operation among scientists and the co-ordination of scientific research.

REPORT OF THE BRITISH COMMONWEALTH SCIENTIFIC OFFICIAL CONFERENCE

Many of the recommendations of the Royal Society Empire Scientific Conference were subsequently endorsed by the Official Conference. A report containing the resolutions of the Official Conference has been

published and contains the resolutions of the Royal Society Conference as an appendix.

THE OPENING CEREMONY

The Conference was opened by His Majesty The King, accompanied by Her Majesty The Queen, on Monday, 17 June, at 11 a.m., in the Beveridge Hall of the Senate House, University of London. After the speeches, the leader of each delegation presented the members of his delegation to Their Majesties The King and Queen. Members of the delegations from the Colonies and from Eire were presented by the President of the Royal Society.

The speech of the President of the Royal Society
Sir Robert Robinson

As President of the Royal Society and in loyal devotion to the Society's Royal Patron, I humbly offer to Your Majesty our mindful appreciation of your presence, accompanied by the Queen, on this memorable occasion.

Once more in peaceful freedom, scientific men, delegates from all parts of your Empire, have come together for the co-operative exchange of ideas and information, under the auspices of the Royal Society.

We are deeply grateful to Your Majesty for your gracious consent to open this first Empire Scientific Conference.

The Society received its Royal Charter from its Founder Patron, King Charles II, in the year 1662, and since that time many historic events have brought the Society into close relation with the affairs of Empire.

The famous voyage of Captain Cook in His Majesty's Ship *Endeavour* was undertaken at the instance of the Society, particularly for the purpose of the accurate determination of the transit of Venus. It led to the birth of two Dominions as well as of many Colonial possessions. One of my predecessors, the illustrious Sir Joseph Banks, took part in the expedition as a young botanist, and has not inaptly been called ' The Father of Australia.'

Many other expeditions and ventures have been initiated by the Society, for instance, the voyage of H.M.S. *Challenger*, and these have extended knowledge of the oceans and the territories in the great expanse of your Imperial and Colonial domain.

Other activities to mention but a few, have been magnetic, meteorological, geodetic and seismological surveys and studies of tropical diseases.

During the war, the Society has been a focal point for discussion of matters of mutual interest by scientific representatives of the Dominions, many of whom acted as liaison officers in London.

It became evident that many problems needed closer consideration and these included the fuller use of Science for the benefit of mankind, the improvement of scientific communications and other questions relating to the organization of science within the Empire, and finally the machinery of international co-operation.

Arising from these meetings it was resolved that it would be a wise procedure to call together, soon after the war, representatives of a wide range of the sciences from the various parts of the Empire, in order to facilitate an exchange of views on scientific matters of mutual concern.

This decision is recorded in the ' Royal Society ' Report of the British Commonwealth Science Committee. It was hoped that recommendations

for desirable action would be forthcoming and the discussions would lead to a fuller appreciation of the problems that await solution, and would stimulate research in many directions.

With the cordial concurrence of the various governments of the British Empire, the Royal Society has accordingly organized this Conference, and scientific delegates from the Dominions, from India, from the Colonies and from the United Kingdom are gathered this day to receive from Your Majesty approval of the enterprise.

The delegates will be afforded ample opportunity to tell the story of the organization of scientific effort in the regions they represent.

We recognize the influence of environment on the healthy growth of an organism and would not seek to impose a uniform pattern of development. Nevertheless, there are many common factors, and it cannot fail to come to pass that many will profit in the future from knowledge of the experiences of others in broadening the basis of scientific work and its applications.

The many topics that the Conference will discuss are set out in detail in the programme, and it is certain that others will arise spontaneously.

Among the more significant are the problems of agricultural science in relation to the varying conditions that obtain in the Empire, and those of medical science, for example, the physiological effects of work in the tropics, and the control of infectious and transmissible diseases. The Conference will consider questions of land utilization and conservation, the survey of mineral resources, and the industries that can arise from the development and proper use of the bountiful material products of the Empire.

Provision has been made for the discussion of the important question of the improvement in the dissemination of scientific information, the securing of greater uniformity in standards and the improvement of co-operation with existing and projected international scientific organizations.

Particular value attaches to measures that may be prepared for increasing the mobility of research workers in the Empire, so that they may be located in the place where their labour can be most fruitful. Much has been done in this direction, but far more remains to be accomplished. We are assured that Your Majesty would favour more effective ways which may be designed to make the Empire as a whole more accessible to scientific workers.

Science acknowledges only the limitations of man's mind and of human powers of observation, experiment and reasoning ; it knows no frontiers of nationality or sect.

The first secretaries of the Royal Society were in correspondence with the experimental philosophers in all lands and the ideal of the widest possible collaboration, set before us by our Founders, has ever since been zealously pursued. It is our ambition to make the Empire an example to the world of what may be achieved by friendly intellectual intercourse, the clash of one mind on another and by mutual criticism and encouragement.

Our conferences will be held in London, in Oxford and in Cambridge.

There will be many opportunities for visits to laboratories for the most part in the afternoons. Certain major matters will be discussed in the mornings, but we also attach great importance to the evening sessions which will be devoted, not only to a variety of topics already selected, but

also to that informal exchange of ideas which alone can ensure the full success of the Conference.

If I may venture to speak from personal experience of international gatherings it has often been the unrecorded proceedings that have proved the most significant.

It has been arranged that the Royal Society's Conference will be followed by one of the scientific representatives of the Governments of the Dominions and India.

Doubtless it will transpire that the matters discussed in the present Conference will have been so crystallized that recommendations may be made to the Conference of officials for implementation, if approved, by the various governments concerned.

Your Majesties have been informed that the Royal Society is celebrating the tercentenary of the Birth of Isaac Newton in the week commencing on the 15th of July. The actual date was Christmas Day, 1642, but a commemoration in 1942 was clearly impossible.

Delegates from foreign academies have been invited to this celebration and the scientists from the Empire will also have the opportunity to pay their tribute to Newton's memory.

We are indeed grateful to Your Majesty for invitations to attend Royal Garden Parties at Buckingham Palace on this occasion.

In the early days of the Royal Society its experimental inquiries appeared to many to be far removed from any conceivable practical consequences. Thus Pepys, President from 1684–1686, records that King Charles II himself 'mightily laughed at Gresham College for spending time only in weighing of ayre and doing nothing else since they sat.' We know better now. Man's power over Nature has been enormously advanced through his application of scientific knowledge, but this power is fraught with terrible dangers unless it is used wisely, controlled wisely, and for the happiness and welfare, rather than the misery and destruction, of mankind.

The discovery of the means of releasing the energy locked in matter is a great triumph of research and the work of no one man contributed so much to it as that of Lord Rutherford, a great son of the Empire.

But the new knowledge can be used for good or for evil and though the layman must share the responsibility for the choice, the scientists have a special part to play, in the exercise of their consciences, to ensure that their knowledge is used for the noble purpose.

I therefore believe that this Conference will be of the utmost value in affording the opportunity for discussion of this topic of such overwhelming importance for the future of the civilized world.

We ask for Your Majesty's gracious favour in the undertaking of this Conference by the Royal Society, that it may be a fount from which science may flow freely throughout the Empire, and may be used for the welfare and happiness of those who abide in Your realms, bearing a message of hope, through its constructive work, to a sore-stricken world.

The speech of His Majesty The King

It gives me great pleasure to be here to-day to open the Empire Scientific Conference, and to greet the delegates. It is the first conference of its kind

but I hope it is destined to be the beginning of an era of closer contact in scientific affairs within the Empire.

Nothing can take the place of personal contacts. However clearly a man may write, the spoken word has a directness of appeal which cannot be achieved in any other medium.

I am, therefore, very glad to know that you will discuss whether there should be more such meetings as this Conference and this is a question which, I do not doubt, you will answer in the affirmative. Furthermore, I hope that you will arrange meetings of a more specialized character; and that, whether the meetings be general or related to specific activities, they should not always be held in London but periodically in one or other of the capital cities of the Empire.

We have recently emerged from a terrible war in which, with God's help, we and our Allies were victorious. For six years, the means of waging war and securing peace have filled our minds and occupied our days. Our energies were concentrated for the most part upon destroying the power of our enemies. Not only had old weapons to be continually improved, but new ones had to be devised, and in this work the scientists played an essential part. But not all the work of scientists had destructive ends in view. Great advances have been made which are of the highest importance to civilization in times of peace. They cover a vast range and I will mention only one or two of the more important.

In penicillin we have a powerful means of fighting disease, the potentialities of which have certainly not yet been fully explored. New insecticides enable us to control and perhaps to defeat the malarial mosquito.

We have increased our knowledge of the effects of shock on the nervous system and of the reactions of the human body to rapid changes of temperature and pressure. We have made great strides in the discovery and production of organic chemicals and synthetic drugs.

Our necessities have led us to make substantial advances in agriculture and veterinary science. We are also better able to forecast the weather, a development which has been, and must increasingly be, based upon international co-operation. It is, of course, of great importance to the growth of civil aviation. So too with radar, which, developed for our protection from attack by hostile aircraft, will contribute greatly to the safety of navigation by air and sea. New methods of wireless communication have been evolved, and electronic methods have been adapted to the timing of events which occur so rapidly as to be beyond the scope of any purely mechanical system. Jet-propulsion has opened up the possibility of flights at speeds greater than that of sound.

Finally, the production of the atomic bomb through scientific prediction and scientific collaboration has brought home to the world with terrifying directness the fact that the increase in man's knowledge of the material universe may be fraught with infinite possibilities of good and evil. This must never be used as an argument against scientific research. It should rather lead us all to seek for ways and means of increasing our respect for moral principles and to endeavour under God's guidance to reject the evil and choose only the good.

There is good reason to believe that the nearness of the war to the civilian population in their homes and in their daily lives, has brought about

an awareness of the power of the scientific method, and a realization that what has helped to win the war will also be of service in making the world healthier, happier and more prosperous. We now have to make good the wastage of the last six years and restore our shattered economy, and scientific research must play a great part in reconstruction. It is, therefore, very gratifying to me to note that my Governments in the United Kingdom and in the Dominions and India have all made provision for increased expenditure upon scientific education and research, in spite of many other calls which they will have to meet. We must see to it that the available resources, both in money and manpower, are efficiently applied.

The Empire is a laboratory richly stored with materials and it covers a very wide range of terrestrial and climatic conditions. By co-operation in the Commonwealth, we can, therefore, develop a greater and wider field of scientific investigation than any other community, always excepting the United Nations Organization, with which we intend to work to the full. The nations of the British Commonwealth will, I am sure, be ready to play their part.

I now declare the Empire Scientific Conference open, and I pray that God may prosper your deliberations.

The speech of the Leader of the Canadian Delegation
Dr C. J. Mackenzie

Your Majesties, my Lords, Ladies and Gentlemen: As head of the delegation from our senior Dominion it is my pleasant privilege this morning to respond on behalf of the delegates from the various parts of the Empire, and I am sure we all have been moved by the graciousness of His Majesty and the Queen in appearing personally to greet us so warmly, and to open this Conference with such expressions of understanding and good wishes.

We who come from distant lands where our problems assume different forms, and with our outlook coloured by local circumstances, will no doubt bring to this Conference divergent points of view on many detailed problems—but in our devotion to the Crown as the essential and unbreakable tie that binds us together we are united and indivisible. Because the opportunity comes less often to us, we appreciate more than words can express this honour of being welcomed in person by a King and Queen we have learned to honour, revere and love for the staunch courage and deep sympathy which brought so much comfort and encouragement to the defenders of this island during the war, and stirred the hearts of all peoples of the Empire, and of other lands as well. On behalf of those for whom I speak, I beg leave to couple with a pledge of our lasting loyalty and devotion the hope that Your Majesties may long be spared to reign over a restored and happy England, a strong and useful Empire in a world of enduring peace.

To you, Mr President, as the head of a Society with a record of nearly 300 years of eminent service to science and to the State, we would like also to express our appreciation of the arrangements which have made it possible for us to gather together in conference to-day, and we are all confident that the atmosphere of understanding in which the plans for both Conferences have matured will be maintained during our deliberations

and that out of our combined experience and wisdom there will emerge a satisfactory scheme of peacetime scientific co-operation for the Empire.

There can be no doubt, Mr President, that the inspiration for this meeting is to be found in the almost passionate determination on the part of those scientific workers who were drawn so closely together in war, that the splendid co-operation we achieved under the stress of battle shall not be lost in peace but in a fashion fitted to the purposes of peace, be retained for the common good.

At this time, perhaps more than at any other moment in history, it is appallingly clear that wars bring nothing but tragedy, suffering and loss to vanquished and victor alike, and that there is little to be found on the credit side, but we can say as Canadians, and I am sure those of the other Dominions will echo our words, that out of the splendid scientific co-operation we achieved under the stress of war when the stakes were high, we did learn what are the real essentials of effective co-operation. We learned that effective co-operation is built on respect for the work of others in different fields, we learned that all facets of research, from work of a most fundamental character to the more immediate *ad hoc* applications of scientific techniques, are all important and necessary for a general advance —there is no more a place to-day for scientific isolation within a nation than there is meaning in national isolationism in this international world we live in, and if Empire co-operation and international co-operation in science is to become a reality, we, in our deliberations, must never lose sight of the cardinal principles we learned at such a great price in human sacrifice.

Mr President we meet here to-day as realists tempered in the heat of a terrible war of survival. We know that it is easier to co-operate in war than in peace and we also know why, but we also, I suggest, know better than most people the great dividends in human and social benefits that can flow from scientific co-operation for peaceful pursuits and I suggest this Conference itself, to which many of us have come long distances and at the sacrifice of time we can ill afford, is the best evidence of our quiet determination to arrive at some workable scheme of liaison and exchange of information and personnel that will be of value to the Empire and will also, we hope, serve as an example for a wider and probably more important international scheme that may be evolved, and accordingly we all, I am sure, most reverently join His Majesty in his prayer that God may prosper our deliberations.

THE ORGANIZATION OF SCIENCE

The first three days were devoted to the description and discussion of the organization of science in the countries of the Commonwealth. At an evening meeting at the Royal Society the Australian delegation presented a film illustrating the scientific work of the C.S.I.R. in Australia.

During these discussions many interesting differences in organization emerged. The exchange of views enabled delegates to perceive the importance of the problem of preserving a proper balance between the development of controlled objective research under official guidance and the tradition of freedom for academic work upon which so much of value

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had depended in the past. It became clear, however, that the conditions in the countries of the Commonwealth called for different approaches to the problem, and exchange of views provoked useful suggestions.

The discussions included an account of the scientific problems of the Colonial Empire and delegates supported recommendations for regional approaches, based largely upon particular Dominions, to the scientific problems of geographically homogeneous groups of Colonies.

LIST OF MORNING DISCUSSIONS

(*a*) A survey of some outstanding problems in agricultural science in the Empire.

(*b*) A survey of some outstanding problems in medical science.

(i) Discussion of the physiological and psychological factors affecting human life and work under tropical conditions and in industry.

(ii) The etiology and control of infectious and transmissible diseases, particularly those which are insect-borne.

(*c*) Discussion of the present state of the science of nutrition with particular reference to the special problems of the Empire, including the nutritional status of the indigenous peoples of the Colonies.

(*d*) Discussion of modern methods of mapping and exploration by air, including the use of radio technique in ordnance survey with special reference to particular parts of the Empire.

(*e*) Discussion of measures for improving scientific information services within the Empire. Subjects to be discussed include indexing, abstracting, special libraries and microfilms.

(*f*) Discussion of methods of improving the interchange of scientists throughout the Empire, including a discussion on the future of the scientific liaison offices that have been established during the war. (*Note :* The functions of these offices are relevant also to the first part of (*e*) above.)

(*g*) Discussion of Empire co-operation in the scientific field with existing and projected international organizations.

(*h*) Discussion of measures which might be taken to secure greater uniformity in physical standards of measurement and the use of units, terms and symbols. (*Note :* This is of urgent importance now and is vital for the effective development of international co-operation in science.)

(*i*) Discussion of the collection and interchange of scientific records and experimental material including the safeguards that will have to be taken to minimize the risk involved in the distribution of plants, seeds and animals.

(*j*) Discussion of the problems of land utilization and conservation throughout the Empire. This discussion is designed to bring together the various factors affecting land utilization and conservation including forestry, soil erosion, irrigation, etc.

(*k*) Discussion of the need for a co-ordinated survey of the mineral resources of the Empire and for operations on a much larger scale than hitherto.

(*l*) Discussion of the natural products of the Empire and the chemical industries that are or might be based on them.

(*m*) Post-war needs of fundamental research.

(*n*) Discussion of an all-African organization for the co-ordination of scientific work within the African Continent.

STEERING COMMITTEE FOR THE CONFERENCE

The President of the Royal Society

Sir Robert Robinson

Chairman

Sir Henry Tizard, F.R.S.

The Officers of the Royal Society

Sir Thomas Merton, *Treasurer*
Sir Alfred Egerton, *Secretary*
Sir Edward Salisbury, *Secretary*
Professor A. V. Hill, *Foreign Secretary*

Sir Shanti Bhatnagar, F.R.S.
Dr D. M. Blair
Professor C. J. Mackenzie
Dr E. Marsden, F.R.S.
Sir David Rivett, F.R.S.
Professor B. F. J. Schonland, F.R.S.

STEERING GROUPS FOR THE CONFERENCE

Discussion (*a*)

Agricultural science

Chairman—Sir Frank Engledow, F.R.S.

Recorder—Mr F. Hanley

Dr E. S. Archibald
Mr A. G. Beattie
Khan Bahadur Mian Mohammed Afzal Husain
Sir Theodore Rigg
Dr A. R. Saunders
Dr H. C. Trumble

Discussion (*b*, i)

Medical science—factors affecting human life under tropical conditions

Chairman—Professor C. H. Best, F.R.S.

Recorder—Dr J. S. Weiner

Dr S. Adler
Dr F. M. Burnet, F.R.S.
Dr E. H. Cluver
Professor C. E. Hercus
Sir Edward Mellanby, F.R.S.
Colonel Sir S. S. Sokhey

Discussion (*b*, ii)

Medical science—etiology and control of infectious diseases

Chairman—Professor C. E. Hercus

Recorder—Dr C. H. Andrewes, F.R.S.

Dr I. B. Bull
Professor A. T. Cameron
Professor W. E. Le Gros Clark, F.R.S.
Dr E. H. Cluver
Professor W. A. E. Karunaratne
Sir Edward Mellanby, F.R.S.
Colonel Sir S. S. Sokhey

Chairman—Professor R. A. Peters, F.R.S.

Recorder—Dr B. S. Platt

Dr E. H. Cluver
Professor J. B. Collip, F.R.S.
Professor C. E. Hercus
Mr A. Glendon Hill
Mr H. R. Marston
Sir Edward Mellanby, F.R.S.
Colonel Sir S. S. Sokhey

Discussion (*d*)

Mapping by air

Chairman—Dr E. S. Moore

Recorder—Lieut.-Colonel C. A. Hart

Dr E. C. Bullard, F.R.S.
Major W. R. Junner
Dr M. S. Krishnan
Sir John Madsen
Professor B. F. J. Schonland, F.R.S.

Discussion (*e*)

Scientific information services

Chairman—Dr C. J. Mackenzie

Recorder—Professor R. S. Hutton

Sir Alfred Egerton, Sec. R.S.
Dr E. Marsden, F.R.S.
Sir David Rivett, F.R.S.
Professor B. F. J. Schonland, F.R.S.
Dr H. H. Storey, F.R.S.
Mr D. N. Wadia.

Discussion (*f*)

Interchange of scientists

Chairman—Sir Alfred Egerton, Sec. R.S.

Recorder—Dr W. B. Mann

Dr D. M. Blair
Sir Jnan Ghosh
Dr C. J. Mackenzie
Dr E. Marsden, F.R.S.
Sir David Rivett, F.R.S.
Dr J. Smeath-Thomas
Mr F. E. V. Smith
Sir Henry Tizard, F.R.S.

Discussion (*g*)

Empire co-operation in science

Chairman—Professor A. V. Hill, For. Sec. R.S.

Recorder—Professor F. J. M. Stratton

Sir Shanti Bhatnagar, F.R.S.
Mr J. C. Eyre
Dr Alexander King
Dr C. J. Mackenzie
Sir Theodore Rigg
Sir David Rivett, F.R.S.
Professor B. F. J. Schonland, F.R.S.
Sir Henry Tizard, F.R.S.

Uniformity of physical standards

Chairman—Dr E. Marsden, F.R.S.

Recorder—Dr J. C. Evans

Sir Charles Darwin, F.R.S.
Dr C. J. Mackenzie
Sir John Madsen
Professor P. C. Mahalanobis, F.R.S.
Dr S. Sambursky
Professor B. F. J. Schonland, F.R.S.

Discussion (*i*)

Collection of scientific records

Chairman and Recorder—Sir Edward Salisbury, Sec. R.S.

Dr S. Adler
Professor A. T. Cameron
Mr J. K. Chorley
Dr A. R. Saunders
Professor Birbal Sahni, F.R.S.
Professor F. G. Soper
Dr H. C. Trumble

Discussion (*j*)

Land utilization and conservation

Chairman—Sir Theodore Rigg

Recorder—Mr G. V. Jacks

Brigadier R. A. Bagnold, F.R.S.
Mr A. Glendon Hill
Professor E. S. Hills
Professor J. N. Mukherjee
Dr L. T. Nel
Dr R. Newton

Discussion (*k*)

Mineral resources of the Empire

Chairman—Sir Thomas Holland, F.R.S.

Recorder—Professor W. R. Jones

Mr L. J. D. Fernando
Professor E. S. Hills
Dr M. S. Krishnan
Dr E. Marsden, F.R.S.
Dr E. S. Moore
Dr L. T. Nel

Discussion (*l*)

Natural resources of the Empire

Chairman and Recorder—Dr J. L. Simonsen, F.R.S.

Sir Jnan Ghosh
Professor E. J. Hartung
Professor O. Maass, F.R.S.
Mr F. E. V. Smith
Dr J. Smeath-Thomas
Professor F. G. Soper

Chairman—Sir David Rivett, F.R.S.

Recorder—Professor P. M. S. Blackett, F.R.S.

Sir Shanti Bhatnagar, F.R.S.
Sir Alfred Egerton, Sec. R.S.
Dr J. C. Hopkins
Professor W. A. E. Karunaratne
Dr C. J. Mackenzie
Dr E. Marsden, F.R.S.
Sir Edward Salisbury, Sec. R.S.
Professor B. F. J. Schonland, F.R.S

Discussion (*n*)

Co-ordination of scientific work in Africa

Chairman—Professor B. F. J. Schonland, F.R.S.

Recorder—Mr E. Boden

Mr C. V. Carstairs
Mr J. K. Chorley
Mr R. Daubney
Lord Haley
Dr P. J. Du Toit

LIST OF PAPERS PREPARED FOR THE ROYAL SOCIETY EMPIRE SCIENTIFIC CONFERENCE

Note: The figures, in brackets, after each title, denote the volume and page where the paper will be found.

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COLONIES . . . . . Organization of research in respect of the Colonies—(Memorandum prepared by the Colonial Office for the Commonwealth Scientific Official Conference) (i, 110).

INDIA . . . . . Organization of science in India and some of the problems in applied science—Sir Shanti Bhatnagar, O.B.E., F.R.S. (i, 119).

NEW ZEALAND . . . . Organization of scientific research in New Zealand—Dr E. Marsden, C.M.G., C.B.E., M.C., F.R.S. (i, 136).

PALESTINE . . . . . Scientific organization in Palestine —Dr S. Sambursky (i, 139).

SOUTH AFRICA . . . . The organization of scientific research and development in South Africa. (A statement by the Scientific Adviser to the Prime Minister) (i, 140).

SOUTHERN RHODESIA . . . Organization of scientific activities in Southern Rhodesia (i, 153).

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The Royal Society . . .	Notes on current scientific researches in the United Kingdom (**i**, 172).

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Daubney, R., C.M.G., O.B.E. .	Animal husbandry in East Africa in relation to human food production (**i**, 330).
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Husain, Khan Bahadur Mian Mohammed Afzal.	A survey of some outstanding problems in agricultural science in India (**i**, 347).
Marston, H. R.	Problems in agricultural science in Australia : ruminant nutrition and general agricultural education (**i**, 362).
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Morning Subject (*b*, i)

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Mackworth, Dr N. H.	Definition of the upper limit of environmental warmth by psychological tests of human performance (i, 423).
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Bell, Dr Muriel E.	The present state of the science of nutrition with particular reference to the special problems of the Empire including the nutritional status of the indigenous peoples of the Colonies (i, 544).
Brown, Dr H. H.	Memorandum on ' Food from colonial fisheries ' (i, 563).
Clements, F. W.	The present state of the science of nutrition (human) with particular reference to the problems of Australia (i, 565).
Glendon Hill, A.	The selection and improvement of food plants (i, 568).
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PLATT, Dr B. S. . . .	The nutritional status of the indigenous peoples of the Colonies (**i**, 587).
WAKEFIELD, A. J., C.M.G. . .	The policy of full production in colonial agriculture (**i**, 608).

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DOMINION FOREST SERVICE . .	The use of air photographs for forest survey in Canada (**i**, 626).
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LOVATT, E. H.	Soil mechanics in New Zealand (**ii**, 616).
VAN DER MERWE, C. R. . .	Soil survey in the Union of South Africa (**ii**, 619).
MODRINIAK, N.	Problems of applied geophysics in the Dominion of New Zealand (**ii**, 620).
NATIONAL ROAD BOARD SOUTH OF AFRICA.	Soil mechanics (**ii**, 623).
NAUDE, Dr T. J. . . .	Biological assay—(insecticides) (**ii**, 625).
NAUDE, Dr T. J. . . .	Pest control—(insects) (**ii**, 626).
PAZZI, J. J. O.	Developments in soil mechanics including engineering developments (**ii**, 628).
RIGG, Sir Theodore . . .	Minor element deficiency in New Zealand (**ii**, 630).
RIPLEY, Dr P. O. . . .	Modern developments in soil mechanics (**ii**, 637).
DU TOIT, Dr P. J. . . .	Game in relation to animal diseases (**ii**, 650).
DU TOIT, R.	Arthropod pests of animals and their control in the Union of South Africa (**ii**, 657).
VERNON, Dr T. R. . . .	Microbiology in New Zealand (**ii**, 660).

RECORD OF PROGRAMME OF THE ROYAL SOCIETY CONFERENCE

The Conference was formally opened by His Majesty The King, accompanied by Her Majesty The Queen, at 11 a.m. on Monday, 17 June 1946. The opening ceremony took place in the Senate House of the University of London, which had been kindly lent by the Senate for the occasion. The opening ceremony was followed by lunch, and after lunch the Conference held its first session—' the United Kingdom contribution on general scientific organization.' The High Commissioner for India gave a reception at India House in honour of the Indian delegates.

' The general scientific organization in Canada, New Zealand and the Colonial Empire ' was the subject of the morning session on Tuesday, 18 June. The Parliamentary and Scientific Committee gave a tea at the House of Commons. The Rt. Hon. Sir John Anderson received the guests. The Australian film ' Science in Australia ' was shown to the delegates at the Royal Society on the same evening.

On Wednesday, 19 June, the morning session was concerned with ' the general scientific organization in Australia, South Africa and India.' The delegates had lunch at Burlington House and immediately after left for a visit to the National Physical Laboratory where there was a reception. The delegates were entertained to tea after having been shown round the Laboratory. The Rt. Hon. Viscount Addison, Secretary of State for Dominion Affairs, received the guests at the cocktail party which the Government gave in Lancaster House.

Thursday, 20 June, opened with a discussion on ' methods of improving interchange of scientists, and the future of scientific liaison offices.' In the afternoon the delegates attended an ordinary meeting of the Royal Society in the course of which they heard the Royal Society Ferrier Lecture.

The morning discussion on Friday, 21 June, was on ' the post-war needs of fundamental research.' Delegates who are chemists were entertained to lunch by the Chemical Society and the delegations from India and Burma were entertained to lunch by the Burmah Oil Company. In the afternoon a reception in honour of the delegates was held by the English Speaking Union, Lord and Lady Wakehurst received the guests. Tea was served later. Delegates who are members of professional Chemical Institutes in the Dominions were entertained to dinner by the Royal Institute of Chemistry.

The subject of the morning session of Saturday, 22 June, was ' the natural products of the Empire and chemical industries that are or might be based on them.'

In the afternoon delegates travelled to Cambridge and, during the evening, heard an interesting talk on ' Cambridge and its history ' by Mr G. F. Hickson.

On Monday, 24 June, two sessions were held simultaneously. One on ' the problems of agriculture ' and the other on ' the need for a co-ordinated survey of the mineral resources of the Empire.' In the afternoon the departments open for visits by the delegates were the Cavendish Laboratory,

the Biochemistry Laboratory, the Molteno Institute (Cellular Physiology) and the Low Temperature Research Station.

The ceremony of the conferment of Honorary Degrees on five of the delegates took place in the afternoon. The Vice-Chancellor of the University of Cambridge (Mr H. Thirkill) conferred the degrees and later entertained all the delegates at a sherry party in Clare College.

In the evening informal discussions took place on a number of subjects including, ' blood groups,' ' geophysics in South Africa ' and ' the role of minor elements in nutrition of plants and animals.'

On Tuesday, 25 June, two discussions took place simultaneously during the morning. One on ' greater uniformity in standards of measurement ' and the other on the ' collection of scientific records and material and risks involved in the distribution of plants, seeds and animals.' In the afternoon visits were made by various parties to the University Farm, the Plant Breeding, Potato Virus, Horticultural Research Station, Empire Potato Collection, Animal Research Station, Department of Mineralogy, Department of Geology and the Department of Engineering.

Informal discussions in the evening included ' cosmic rays,' ' soil physics,' ' physical properties of viruses ' and the ' Pentoxyleae—a new group of Jurassic Gymnosperms from the Rajmahal Hills, Behar.'

Wednesday, 26 June, started with an excursion to Ely. The Dean of Ely (The Very Rev. Lionel Blackburne) welcomed the delegates and conducted them round the Cathedral. A garden party was given in the afternoon by St John's College. Unfortunately the weather was not good on that day and the party was held in the Hall. The Master of St John's (Mr E. A. Benians) received the guests.

The evening's informal discussions included ' the role of the village pond in the rural economy of India,' ' generation of high energy particles,' ' extra-terrestrial radio waves ' and ' problems of antarctic research.'

The subject of the discussion in the morning of Thursday, 27 June, was ' scientific information services.' Visits were made in the afternoon to Pest Control Ltd., Unit of Animal Physiology, Department of Physiology, Pye Radio Ltd., Chemical Laboratory, Laboratory of Physical Chemistry, Laboratory of Colloid Sciences, Department of Pathology, Department of Experimental Medicine and Department of Medicine. The subjects of the evening's informal discussions included ' oceanic geology,' ' the use of tracer elements and arrangements for their supply ' and ' constitution in cattle and its relation to pests and diseases.'

The morning discussion on Friday, 28 June, was on the subject of ' the etiology and control of infectious and transmissible diseases.' In the afternoon visits were made to the Cambridge Instrument Company, Department of Zoology, Department of Botany, Department of Agriculture, Nutritional Laboratory and Animal Pathology Laboratory. In the evening the Mayor of Cambridge (Lady Bragg) held a Civic Reception at the Guildhall in honour of the delegates.

During the stay of the Conference in Cambridge the following establishments were open to visits by delegates. Cambridge University Press, Strangeways Research Laboratory, Department of Metallurgy—Chemical Laboratory, Department of Mathematics, Department of Geography, the Scott Polar Institute, Laboratory of the Physics and Chemistry of rubbing

solids, Department of Geophysics and Geodesy, Observatory and Solar Physics, Entomological Field Station, Department of Genetics, Botany School Field Station, Radiotherapeutics Laboratory, Department of Anatomy, Department of Physiology and the Department of Psychology.

The delegates were housed in groups of varying numbers in the following Colleges : Christ's, Emmanuel, Gonville and Caius, King's, Magdalene, Pembroke, St John's, Selwyn, Trinity and Trinity Hall.

The Conference Centre was at the Arts School which had been kindly lent for the purpose. This contained a lecture room for the discussions, a reading room for the delegates, an information bureau, post office and telephone facilities, and offices. An additional lecture room was available at the Cavendish Laboratory and was used on several occasions.

On Saturday morning, 29 June, the delegates left Cambridge for Oxford. On arrival the President of Magdalen College (Sir Henry Tizard) gave a short introductory talk. A garden party for the delegates was given at Wadham College later in the afternoon. In the evening the Vice-Chancellor of the University of Oxford (Sir Richard Livingstone) welcomed the delegates at a reception given in Rhodes House.

On Sunday, 30 June, many of the delegates went on an all-day excursion of the country round Oxford and had tea at Blenheim Palace.

Monday, 1 July, opened with two simultaneous discussions, one on ' problems of medical science, including a discussion of the physiological and psychological factors affecting human life under tropical conditions and in industry ' and the other on ' modern methods of mapping and exploration by air, including use of radio technique.'

In the early afternoon Honorary Degrees were conferred on four of the delegates at the Sheldonian Theatre. Visits were made to the following : Clarendon Laboratory, where an informal discussion on atomic energy took place, Department of Agriculture with an excursion to Wilcot, and the Wingfield-Morris Orthopaedic Hospital at Headington. A cocktail party was given by the Nuffield Foundation at Christ Church at which Lord Nuffield and Sir William Goodenough received the guests. The subjects of the informal evening discussions included, ' recent advances in chemo-therapy,' ' long-range weather forecasting ' and ' economic ornithology and bird population problems.'

The morning discussion on Tuesday, 2 July, was on ' co-ordination of scientific work within Africa.'

The afternoon visits included a trip to Benson and Nuneham to see the Air Survey, 106 Group, R.A.F., the Department of Botany and the Botanic Garden and the Nuffield Institute for Medical Research (cineradiography). The evening's informal discussions included : ' recent advances in pharmacology,' ' present position in cosmology ' and ' collaborative research in anthropology.'

The morning discussion on Wednesday, 3 July, was on the subject of ' nutrition.' The afternoon visits included the Clarendon Laboratory (meteorology of the upper atmosphere), Department of Forestry and Imperial Forestry Institute at the School of Forestry, and the Institute of Social Medicine.

The Mayor of Oxford (Mr David Oliver) received the delegates at the Town Hall in the afternoon and entertained the guests to tea. In the

evening informal discussions took place on ' recent developments and applications of infra-red work in chemistry and physics ' and ' hormones.'

On Thursday, 4 July, a party of delegates paid an all-day visit to the Telecommunications Research Establishment at Great Malvern. The morning discussion was on ' land utilization and conservation.' In the afternoon delegates attended a lecture on penicillin at the Pathology Laboratory. Later, visits were paid by various parties of delegates to the Physical Chemistry Laboratory, Biochemistry Laboratory, Pharmacology Laboratory, Zoological Laboratory, Physiological Laboratory and Clarendon Laboratory (physics). In the evening the delegates attended a reception at Magdalen College, The President of Magdalen (Sir Henry Tizard) received the guests.

While in Oxford delegates were housed in the following Colleges : Balliol, Brasenose, Christ Church, Corpus Christi, Exeter, Hertford, Lincoln, Magdalen, Merton, New College, Queen's, St John's, Trinity, University, Wadham and Worcester. The reading room for delegates and information bureau were at Rhodes House, in some of the reception rooms kindly lent for the purpose. Post office and telephone facilities were again provided. The morning discussions took place in the Biochemistry and Physical Chemistry lecture rooms. Office accommodation was provided at Keble College.

The Conference returned to London on Friday, 5 July.

The morning discussion on Saturday, 6 July, was on the subject of ' co-operation in the scientific field.' An afternoon reception was held in honour of the delegates by the Society for Visiting Scientists and tea was served. In the evening the Federation of British Industries gave a cocktail party at Claridge's Hotel.

On Sunday afternoon, 7 July, delegates went on a cruise through the Port of London. The trip on the Port's S.Y. *St Katharine* was made possible through the kindness of the Chairman, The Rt. Hon. Sir John Anderson, and members of the Port of London Authority.

The final session of the Conference was held on the morning of Monday, 8 July, at University College. The delegates were entertained to lunch at University College by the Provost (Dr D. R. Pye). Scientific Departments of the College were open to delegates during the afternoon. A discussion, arranged jointly with the British Association, on ' the dissemination of scientific information to the general public ' took place in the afternoon at the Royal Institution. Later a reception was held at the Royal Institution with demonstrations illustrating the history of researches carried out in the Institution and its Davy Faraday Laboratories.

ORGANIZATION OF SCIENTIFIC RESEARCH

AND

CURRENT SCIENTIFIC RESEARCH

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Sir EDWARD APPLETON (*Organization of Government Science in the United Kingdom*).

It is convenient to think of the large-scale pattern of scientific research in this country as a *triangle*, with university science, industrial science and government science at its corners. Each corner has links with the other two. It is my task this afternoon to say a few words about *part* of what goes on at the government science corner of the triangle and also something about the two links that corner has with industrial science and university science. I used the phrase ' part of what goes on ' because I leave agricultural and medical science to my two colleagues who are to follow me. Also I shall have nothing direct to say on science for defence.

Now during the war many people appeared to have heard for the first time of the work of government scientists. Indeed some people seem to think that scientists had never before been mobilized to work on problems of national importance. It is quite true that very many scientific workers from the universities and industry placed their services at the disposal of government departments during the war, and so increased the volume of scientific effort and achievement ; the main framework of the government scientific organization was in existence well before the war. There were extensions it is true, but the chief result of the war was the expansion of the staffs and activities of research establishments which already existed.

Now the question may well be asked, ' why has government instituted these scientific establishments to conduct research in particular fields ? ' The answer is, that it is because government is vitally concerned with the *application* of science in the interests of the well-being and prosperity of the community. A modern government undertakes, as a direct responsibility, the active improvement of the welfare of the community ; and certain aspects of such improvements need scientific knowledge. Some of the scientific knowledge required is available, and only needs interpretation and application, and some of it has to be acquired by scientific research. To a steadily increasing extent we can, I think, say that science is being used as the basis of the formulation of government policy.

It has been stated that government accepts responsibility for providing work, food and homes for all of us. These tasks are in addition to those of keeping the nation healthy, and safe from aggression. If you think about these five things, work, food, homes, health and safety, you will understand the more readily the features of the pattern of British Government scientific research.

The Department of Scientific and Industrial Research, which is the

largest of the Government Civil Science organizations, is concerned with *some* of these five objectives. It encourages research and the application of scientific knowledge in industry, because only through the application of science can the industry of the country flourish in a competitive world and so provide adequate employment. The people of this country live in houses, travel on roads, burn fuel, drink water, eat food, and so on. We in the Department conduct research on buildings, roads, fuel, water and the storing and processing of food. Agricultural and medical research are not our province, but are the responsibilities of our sister organizations the Agricultural and Medical Research Councils, in collaboration with the Ministries of Agriculture and Health. During the war also D.S.I.R. played a part in the fifth objective, namely, in trying to keep the nation safe.

Now, as I said earlier, most of the government scientific organizations have been in existence for quite a long time. D.S.I.R. is now thirty years old, and it was established in the middle of the last war. It is worth noting that the Government created it as an expression of forward-looking policy : *not* to conduct research in the interest of the war effort, but to be instrumental in serving the nation, and particularly the industries of the nation, when peace returned. By the original Order in Council which established the Ministerial Committee under the Lord President of the Council, an Advisory Council to the responsible Minister was also constituted. This was, I think, a very early example of the use of a body of independent members *outside* government accepted as advisers on policy for implementation *inside* government. The Advisory Council is a body of experts, which advises the Lord President on the Scientific policy to be followed, and upon all important matters falling within the scope of the Department. Its membership is composed partly of eminent men of science and partly of industrialists, particularly those prominently associated with industrial research. Quite recently two members closely associated with organized labour have been added to it.

As its name implies, the Council is advisory and not executive, and the great influence which it exercises derives largely from the fact that its members are selected by the Lord President as individuals, and are not appointed as representatives of particular interests or organizations.

Now what exactly does the Department do in carrying out its duties ?

(*a*) First, it does research in its own stations. This research is conducted for the benefit of industry and of the community as a whole ; and to meet the requirements of other government departments, e.g. Ministry of Fuel and Power, Ministry of Works, Ministry of Transport, Home Office, etc.

(*b*) Second, it encourages research and the application of scientific knowledge in *industry*.

(*c*) Thirdly, it encourages, as a main source of new knowledge, fundamental research at universities and like institutions. It also seeks to maintain an adequate supply of trained research workers for laboratories of all kinds.

During its history the Department has established, or assumed responsibility for, eleven main research establishments, some of which have regional

or other out-stations. It is of special interest that both the oldest and the largest of these organizations actually were in existence before D.S.I.R. came into being.

The Geological Survey of Great Britain, which not many years ago celebrated its centenary, is our oldest scientific organization. Indeed it is the oldest geological survey in the world. Its work covers the scientific study of the geology of the country, and the collection of exhibits illustrating geological formations and rocks, minerals and fossils from Great Britain and other parts of the world. The advice of the Survey has been in continual demand by government and industry on the distribution of mineral deposits of all kinds, coal, iron, non-ferrous metals and on water supply problems. The Survey is almost always consulted before any important civil engineering work of any kind is begun, and during the war its assistance has been of the greatest importance in finding home sources of minerals essential for war production, minerals which would otherwise have had to be imported.

Our largest establishment is the National Physical Laboratory at Teddington which employs a staff of well over 1,000. I need not describe that well-known institution to you in detail, for you will already have received an illustrated booklet about it and you are to see it for yourselves on Wednesday afternoon next. It conducts research into methods of measurement upon which apparatus for research, and for the control of industrial processes, must ultimately be based. The Laboratory is also responsible for the maintenance of the national standards of mass, length and time ; for the various electrical units and for the accurate determination of the physical constants of materials and for the study of the properties of engineering materials, equipment and so on. In general it gives specialist advice on its own subjects to industry, to other government departments and to the other stations of D.S.I.R.

The original connexion of the Royal Society with the National Physical Laboratory is maintained by way of the General Board and the Executive Committee, both of which are appointed by the President and Council of the Royal Society.

To the nine divisions of the Laboratory there has recently been added a tenth, a Mathematical and Statistical Division which is to be available for consultation by workers in other government departments, universities and industry. It will provide computing services for them, undertake research into new statistical methods and their application in various problems, and into the design and development of new computing machines.

There is not time for me to deal with the other research stations of the Department ; working on building, forest products, fuel, roads, water pollution, food storage and processing, pest infestation of stored products and so on. You will find full details in the D.S.I.R. booklet which you should have received with your other conference papers.

I want, however, to stress the point that our work, with the exception of physics and chemistry which are basic subjects, is organized according to *objectives*. If the subject is timber research then a team of physicists, chemists, botanists, mycologists and so on is organized so that they can make their specialist contributions to the progress of work on timber

considered as a whole. Again, although our objectives are avowedly utilitarian, we have proved time and again the value of the fundamental approach. The growth of science is like the growth of a tree. And if you are interested in the fruit of a tree you must be sure that there is healthy growth in the roots. In this connexion I think we need a new term to describe fundamental work, deliberately undertaken, in some fields which is likely to be of practical importance. I suggest the term ' objective fundamental ' for work in which we are seeking to acquire, physical insight, chemical insight—yes, even atomic insight and understanding—into some matter of practical interest. I might cite as examples of this kind of work, the study of corrosion, the oxidation of fats, or the propagation of radio waves through the troposphere or the ionosphere.

Liaison with other government departments

I now want to say a word or two about the way the D.S.I.R. provides a central scientific service, within its own particular section of the scientific field, to other government departments. We may call them Civil User Departments. It would be uneconomic in scientific manpower for all these executive departments to have research units in *all* the scientific subjects in which they are likely to be interested. The really important thing is first that there should be in each executive department someone who can identify a problem as a scientific one, or suitable for scientific treatment, and second, that he should know where to go to for specialist advice.

There is no standard pattern for the form of this liaison. Most executive departments have their own scientific and technical advisers. Sometimes the adviser and his staff *have* research units, of a complementary character, of their own. Sometimes they don't.

The really important thing is that there should be friendly co-operation between the staffs of different departments *at all levels*. And I venture to claim that this is, in fact, the case.

(By the way I ought to have mentioned that there is an advisory board of independent scientists for each of our ten research stations. These men are chosen for their knowledge and experience. They do not represent interests. Any other government department which may have either a user interest, or a scientific interest, in the work of any one of our stations is represented on the Advisory Board by way of one or more assessors).

Industrial research

I will turn now to the two links of the triangle I mentioned earlier—the links with industrial research and with university research.

Besides carrying out research itself for the government and the community, the main function of D.S.I.R. is to encourage industry to appreciate the value of research, and, once having established the demand for it, to take all possible steps to ensure that the demand is fulfilled. The Department's task has naturally been easier with those industries such as the electrical and modern chemical industry which have grown directly from discoveries made in the laboratory. It is harder with the long-established traditional industries into which the scientist often enters as challenger of long-accepted custom. Gradually, however, it has come to be realized that the

application of scientific knowledge is the only means by which the impact of competition could be met. Although in the long run research pays tremendous dividends, these are seldom achieved immediately, and although the cost of laboratory research is comparatively small its application often involves lengthy and expensive development, besides heavy outlay in the scrapping of out-of-date equipment. To a firm without considerable financial reserves, private research must often appear as a risky venture and beyond the means of the many small firms which make up so large a percentage of British industry.

These difficulties are met, to a great extent, by the Co-operative Research Associations set up with the Department's help. Before the war twenty-one associations or similar organizations were serving the following industries :

iron and steel	boot and shoe
non-ferrous metals	cocoa, chocolate and confectionery
cast iron	flour milling
coal	food processing
electrical	laundry
cotton	paint and varnish
silk and rayon	pottery and refractories
wool	printing
linen	rubber
leather	welding and scientific instruments

Since the beginning of the war, a number of new research associations has been established for shipbuilding, gas coke, internal combustion engines, paper, and other industries, while several others are under consideration. The total expenditure of the associations has increased from £280,000 in 1934 to over half a million pounds in 1939, and it is expected to top the million figure this year.

But however successful co-operative research may be, it can never be generally expected to obtain results, especially in short-range research, more quickly or to be more profitable than research carried out in a firm's own research department, with a staff in a position to appreciate the firm's problems to an extent impossible to any outside organization. Even if a firm is too small to afford a complete research department of its own, it must at least employ some scientific staff if it is to get the full benefit from co-operative research, or indeed to use to the best advantage other facilities for obtaining scientific help. As you may be aware, the government encourages research in *individual firms* by a substantial remission of taxation on research expenditure—both current and capital—in the future.

University science

I want now to say a word about the second link—that between the Department and the universities. During the war it was decided to reserve industrial research teams—in research associations and in private firms—practically intact. In the case of university workers, who are generally more accustomed to work alone or in small groups, no such attempt was made. Looking back on it, this decision seems to me to have proved a wise one. The research establishments of the Government were strengthened by the acquisition of many brilliant minds from the universities, while the

research teams in industrial firms and research associations retained their striking power as units.

The task before us now is that of building up again and strengthening the research groups in universities.

The responsibility for the *general* provision for university research is, of course, that of the University Grants Committee, but we in D.S.I.R. are not thereby precluded from assisting specific activities. Accordingly the Department is assisting research in universities and similar institutions by making grants to individual workers. Such assistance normally takes the form of provision for the employment of research assistants, or for the acquisition of special apparatus. The grants are made on the recommendation of our Scientific Grants Committee, which is a committee of the Advisory Council, the main criterion being the ' timeliness and promise ' of the work proposed.

Another way in which the Department is brought into close contact with universities is in the scheme of maintenance allowances for post-graduate students, which allows them to be trained in the methods of research. In this scheme, young graduates work under the direction of a suitable supervisor for perhaps two years, on a problem usually selected by him. The aim of the scheme is not to turn out a specialist in some branch of research, but to provide the trainee with a real understanding of the scientific method of attack, and to give him the degree of self-confidence necessary for the successful research worker.

The future

So much for what the Department is, and for what it has done in the past. But what about the future? We are not satisfied, and are now busily engaged in examining in close detail how our work should be adapted or re-orientated or expanded to meet post-war needs. Our Advisory Council, for example, has already instituted inquiries into the provision, in this country, for research into mechanical and civil engineering. Another inquiry is also being made into the probable requirements of industry after the war for routine testing and how these can best be met. We are busy building up a strong Intelligence and Information Division in our headquarters whose task will be to assist those who seek our help on the best means of attacking their research problems. The same division will seek to ensure that opportunities for applying new knowledge are not lost.

We believe the main structure of our organization is sound, and will permit us to carry out the programmes that are before us. We do not intend to ask for money, and then think out ways of spending it. The subject of scientific research is to-day in this country receiving much popular—I might almost say glamorous—support. Unfortunately the uninformed think only in terms of money, as if the provision of money for research, or indeed the mere *spending* of money on research, is all that is required. The wise identification of problems for research and the availability of good men with ideas come first. The really important thing in research is to back the man with ideas. If the problems, men and ideas are already there, there is little doubt that the money will be available.

Dr F. M. BURNET (*Organization of Medical Research in Australia*)

Financial support for medical research in Australia comes from three sources. There are several research institutes usually attached to hospitals which were founded by private benefaction and are to some extent currently supported thereby. In two States there are medical research institutes founded and partially maintained by State governments.

The major support, however, comes from the National Health and Medical Research Council which dispenses from a grant of £40,000 per annum. This body is normally not an initiating agent, but merely decides the allocation of available monies amongst the applicants for grants.

At the present time the whole future organization of medical research in Australia is under discussion. The Commonwealth Government has accepted in principle the foundation of a National Institute of Medical Research as an integral part of the University of Canberra. A large establishment with a budget of the order of £125,000 per annum is contemplated.

If a suitable director is obtained and the National Institute is developed in an appropriate relationship to other medical research activities in Australia, this is a highly desirable move. There may be a danger, however, that an Institute at Canberra, remote from the medical schools, will attract most of the government funds available for research with relative starvation of the facilities for attracting and training young men of promise in the universities and clinical schools.

It seems outstandingly desirable (*a*) that Commonwealth support for medical research in Australia should be made through a body, a majority of whose members are experienced in medical and biological research, (*b*) that any National Institute should be regarded as an organic part of the general set up for medical research in the country, and (*c*) that through an executive head the Medical Research Council or other governing body should play a positive part in initiating research projects in providing opportunities for overseas study and in developing superannuation or other methods of protecting the interests of medical research workers.

It is of more importance to Australia than to any other Dominion that the fullest opportunity for reciprocal visits to and from U.K. and U.S.A. should be available to responsible workers in medicine. I should very much like to see some close, but informal, relationship established with the Medical Research Council of Great Britain in such matters as joint investigation of respiratory diseases, arrangements for visiting workers and trainees, and the development of a Commonwealth wide federated superannuation scheme.

Mr C. Y. CARSTAIRS (*Organization of Science in respect of the Colonies*)

By the term 'Colonies' is meant all the territories in respect of which the Secretary of State for the Colonies is responsible to Parliament, i.e. it includes Mandates, Protectorates and Protected States. For present purposes, the South African High Commission Territories, Basutoland, the Bechuanaland Protectorate and Swaziland are also included, although the ministerial responsibility in the U.K. Government is that of the Secretary of State for Dominion Affairs.

The organization of science in and for the Colonies reflects certain historical, geographical, economic and social facts. The total population affected is of the order of some 60,000,000, in groups ranging from a few thousands to over 20,000,000, of many different races, which have reached many different stages of economic, cultural and political advancement, and living under a wide diversity of physical circumstances including wet tropics, desert conditions, temperate conditions and the whole intermediate range.

Apart from Malta, Palestine, Ceylon, Singapore and Hong Kong, the dominant fact from the point of view of scientific organization is the lack of *self-renewing centres of scientific activity* in the shape of universities as known in the U.K., the Dominions and India. Plans are on foot for the establishment of universities in West Africa and the West Indies and for the raising to full university quality of Makerere College in Uganda, but the fruition of these plans lies in the future. In the meantime, the present position means that the Colonies must draw on outside resources for scientists, and that the bases of fundamental science must for the most part lie outside the Colonies. This situation is reflected in the pattern of organization set out in appendix I to the paper circulated (1), viz. :

(*a*) work directly done by government departments, agricultural, medical, veterinary ;
(*b*) *ad hoc* institutions, e.g. East African Agricultural Research Institute (Amani) ; Medical Research Institute, Kuala Lumpur, Malaya ; Imperial College of Tropical Agriculture, Trinidad ;
(*c*) work of U.K. scientific bodies, e.g. Ross Institute, Medical Research Council, Royal Society (expeditions) ;
(*d*) U.K. universities, e.g. Liverpool School of Tropical Medicine in relation to the Alfred Jones Laboratory at Freetown, Sierra Leone ;
(*e*) Rockefeller Foundation, e.g. the Yellow Fever Research Laboratories at Entebbe, Uganda, and Lagos, Nigeria ;
(*f*) work sponsored and financed in whole or in part by industries, e.g. tea, rubber, sisal, sugar, coffee.

The fact that financial assistance towards scientific work in the Colonies has long been available from the U.K. Exchequer (and has been largely increased by the Colonial Development and Welfare Act, 1940–1945), does not alter these fundamental facts, though it increases the opportunities for taking effective action. This situation calls for steps which may be described as follows :

(i) to bring the existence and nature of Colonial scientific problems to the notice of the world of science as represented in the universities and similar institutions ;
(ii) to make work in the tropics a natural, easy and eligible part of a normal scientific career.

Attempts have been made towards (i) by such measures as the institution of the Colonial Research Fellowships scheme ; and the policy of the Colonial Products Research Council, whereby arrangements are made for studies

of the properties and possibilities of Colonial raw materials in the university laboratories best qualified for the particular study. As regards (ii), the chief measure required is so to arrange the terms of service and superannuation of scientific workers in the Colonies that transfers to and from university life (and also the U.K. Government scientific civil service) may be easy and involve no sacrifice of career or emoluments to the individual. Action is in hand to this end.

The increased availability of funds from U.K. sources, though it does not affect the fundamentals of the situation, does throw into relief the problem of the organization and control of scientific work, a matter of great importance and delicacy. The following observation by Dr Vannevar Bush (2) is relevant :

> ' Generally speaking, the scientific agencies of government are not so concerned with immediate practical objectives as are the laboratories of industry nor, on the other hand, are they as free to explore any natural phenomena without regard to possible economic applications as are the educational and private research institutions.'

It follows therefore that in the case of work financed by grants provided essentially for the promotion of development and welfare complete freedom of choice of objective, as in the case of university research, is not generally or entirely appropriate. But the idea of close detailed ' control,' still less such ' control ' exercised at a distance from London, is entirely foreign to the thinking of the Colonial Research Committee and of the Colonial Office, if only for the reason given by Dr C. E. K. Mees (3), of Kodak, in the following words :

> ' No director who is any good ever really directs any research. What he does is to protect the research men from the people who want to direct them and who don't know anything about it.'

But in the case of this category of science, the problem remains, after the research worker has been protected from uninstructed interference, of keeping him in touch with developments in science generally, and with the needs which it is the purpose of his work to meet ; what the President of Harvard meant when he said (4) :

> ' There is only one proved method of getting results in applied science—picking men of genius, backing them heavily and keeping their aim on the target chosen ' ;

the aim being, in Sir Charles Goodeve's words (5), to achieve

> ' a coincidence in a man's head between a piece of knowledge of what can be done and a knowledge of something that is required.'

Finality in this matter is not yet, but useful experience has been gained in the past, and a pattern is emerging, whereby the Director of a scientific organization in the Colonies is associated with a local consultative body, comprising representation of the ' user ' interests involved, together with an advisory focus in this country, to keep the work in touch with wider developments, and to assist the Colonial Office in the discharge of such responsibilities as it may have in the matter.

It is the earnest hope of the Colonial Office that where appropriate they may look to the collaboration of universities and cognate scientific institutions throughout the Commonwealth, and not only in Great Britain.

References

[1] Paper on organization of science—Colonies.

[2] Vannevar Bush, *Science, the Endless Frontier, Report to the President of the U.S. on a Program for Post-war Scientific Research;* U.S. Government Printing Office, Washington, 1945.

[3] Quoted on p. 302 of *The Advancement of Science*, Vol. III, No. 12. British Association for the Advancement of Science.

[4] Ibid., p. 318.

[5] Ibid., p. 303.

Sir John Fryer (*Organization of Agricultural Research in the United Kingdom*)

Members of Conference will find a full account of the organization for agricultural research in this country in a White Paper with the title, 'Agricultural Research in Great Britain,' which has already been circulated to them.

All I need do therefore is to refer briefly to the salient features, so as to facilitate comparison with the arrangements in other fields of science and in other countries of the Commonwealth.

The Agricultural Research Council is a Great Britain body responsible for the scientific oversight of most of the research in the agricultural field that is carried out in England, Scotland and Wales. In this it works in the closest possible association with the Ministry of Agriculture and the Department of Agriculture for Scotland, which are concerned with the application of the results of research to practise and whose ministers have a constitutional responsibility for seeing that the research needed for agricultural policy is carried out.

In Constitution

The Council is a body incorporated by Royal Charter—in this respect resembling the Medical Research Council and like that body is responsible to the Lord President and a Committee of the Privy Council comprising most of the Ministers of the Crown interested in one way or another in agricultural research.

It is perhaps worth noting here that the Council is not in the full sense a government department and the scientists in its employ or with whom they are concerned are not generally civil servants. The Council itself consist of scientists with a small proportion of members with special knowledge of practical agriculture or agricultural administration. Members retire in rotation—serving for about five years. The present Chairman is Lord De La Warr.

So much for the organization at the centre.

Next as to the institutions or people who carry out the research.

For financial and administration purposes, they fall into two groups, (*a*) a range of agricultural research institutes financed on the votes of the

two agricultural departments ; (*b*) various other undertakings directly grant aided by the Council.

This dual source of funds is significant from certain constitutional aspects, but scientifically it is unimportant. My Council makes no distinction in dealing with one or other groups, and as this is a scientific conference I do not propose to refer to it again.

Now as to the nature of their research undertakings.

The Agricultural Research Institutes—of which there are now twenty-one—have been established either to deal with some aspect of agricultural science or with some particular branch of the agricultural industry.

As instances of the former may be mentioned Rothamstead for soil science and the Rowett Institute at Aberdeen for animal nutrition, while instances of the latter are the National Dairy Institute at Reading and the East Malling Fruit Station in Kent. These agricultural research institutes are diverse in their forms of management some being with universities and others under independent boards of management.

The next series of undertakings—next in point of size and numbers employed—are special research grant projects. These projects are of a more or less short term character and are extremely diverse in nature. They may entail very fundamental work carried out by members of university staffs in university departments—they may enable teams of workers at agricultural research institutes to explore some new field and assess its value before deciding on its incorporation into the long term programme, or they may assist extension workers to carry out some piece of field investigation needed to place their advisory work on a sound basis. Instances are, an investigation of the chemical nature of the root excretion from solanaceous plants that stimulate the hatching of the potato root eelworm, exploratory work on the distribution and estimation of deficiency in the scarcer minerals in the soil or on the methods of enumerating wireworm populations as a basis for advisory work.

The great value of the system of making special research grants is its extreme elasticity and the fact that there are no limits to the kind of work the Council can support, always provided it contributes to further knowledge bearing on agricultural science.

Somewhat related to work carried out under special research grants, but of long term character, is the work carried out by the Council's research units. These comprise small teams of people, normally in the direct employ of the Council—established either to obtain more knowledge in some field of pure science essential to agriculture or to assist some distinguished scientist to devote his whole attention to some line of work likely to open up new developments in the agricultural field. Instances of such units are that under Sir Joseph Barcroft dealing with certain aspects of animal physiology, in particular ruminant digestion, that under Dr Wigglesworth with insect physiology, this in association with the University of Cambridge, and that under Dr Quastel on soil metabolism, dealing essentially with the effects of microbiological processes in the soil. These units fulfill a most valuable function in taking care of certain fields of research until it becomes clear whether they should be incorporated in university departments or whether they justify the establishment of a research institute for their full prosecution. They also enable a distinguished

scientist to give his life to some particular research field bearing on agriculture. Finally in this group is the Council's field station at Compton which provides facilities of work on animal diseases in conditions of isolation and also supplies experimental animals to other stations.

Naturally an organization of these dimensions makes considerable demands on scientific manpower and the difficulties of the present situation are too well known to need emphasis here. The Council is doing all it can to assist and in association with the agricultural departments offer both agricultural research scholarships to those who have newly graduated and also special training grants where a research worker has to gain proficiency in some field not included in his earlier training.

As to how the Council carries out its work of oversight in its field. I need hardly say that it assumes in no way a dictatorship. The directors of research institutes frame their own programme and collaboration in the different field is secured mainly by a series of committees or conferences set up by the Council but consisting largely of the research workers themselves and scientists in relative fields.

This committee system also secures our contacts with our sister organizations the D.S.I.R. and M.R.C. in those regions in which our spheres overlap—and common membership also keeps us in touch with other bodies, such as the Colonial Agricultural Research Committee—with which we have many interests in common.

The system I am sure is the right one and its chief limitation at present is the number of meetings which directors of research in responsible positions have to attend. This problem is not confined to the field of the Agricultural Research Council, but it is of great importance to find the best means of making use of the leaders in the scientific world so as to economize their time and ensure that government organizations do not make unreasonable calls on their services. The Council's duty in all this is to make sure that there should be progress in all fields of agricultural research and in particular to see that there are no gaps or that one field does not lag behind.

Finally two recent developments are worth mention.

In pre-war days one of the greatest defects in the organization was the lack of machinery to cover those phases in which research passes into extension work. The research worker too often had to leave his problem at a stage when his results could not be applied directly by the agricultural industry and there was no organized machinery whereby the problems of the farmer could be analysed into their research components and priorities be given to one or the other. These needs are in process of being met by the two agricultural departments, whose Ministers have established Agricultural Improvement Councils (the Scottish body has another name) with the functions of moulding research discoveries to the needs of agriculture and of assessing the latter on behalf of the Agricultural Research Council. In its association with the Agricultural Research Council—through a joint committee—the Agricultural Improvement Council for England and Wales has recommended and the Minister has accepted the recommendation that there should be established a series of experimental husbandry farms, which as one of their principal functions, will offer facilities to agricultural research workers for applying their results under

different systems of husbandry and in different conditions of soil and climate. In Scotland, farms that will offer comparable facilities, are either found in the College Farms or certain hill sheep farms established specially for the purpose.

Secondly, in association with the Agricultural Improvement Councils through a joint committee, the Agricultural Research Council has established a number of survey parties whose function has been to review the different fields of agricultural research and make recommendations for their future developments. The work of these parties has enabled the Council to carry out a complete stocktaking of the undertakings under their oversight. As was to be expected the great developments that have taken place on the one hand in agriculture in Great Britain, and on the other hand in the pure sciences, have rendered the present research organization deficient in a number of directions. Only examples can be given now and the most important perhaps are the need for a much greater attention to animal breeding and genetics, to the physiology of the larger farm animals, to all aspects of vegetable research and to the related subjects of plant pathology, entomology, insecticides and fungicides. In all these fields the Council, in association with the departments has begun to secure the necessary development and it depends largely upon the provision of men, buildings and facilities as to when the various gaps in the research organization can be repaired. In all a very substantial increase in agricultural research is contemplated in the next ten years.

Dr S. L. Hora (*General Scientific Organization*)

Dr Hora regretted that in giving an account of the general scientific organization in the various parts of the Commonwealth, speakers have paid little attention to fisheries, which constitute a basic food industry. In stressing the importance of fisheries from the standpoint of human nutrition, he stated that the ill-effects of starvation and malnutrition due to the famine of 1943 in Bengal could not be wiped off with the provision of adequate cereals, but some protective food was essential to restore health and vigour to the derelict population. In this connexion, setting up of proper organizations for the development of fisheries in the African and Asiatic territories of the British Commonwealth could do a great service in raising the nutritional status of the indigenous peoples of these countries.

Dr Hora drew attention to the following facts which, he stated, stand out clearly from the accounts to which he had been listening with great attention :

(*a*) Gradualness (not slowness) in research and development, except under *ad hoc* exceptional circumstances, was desirable for any long range planning of objective-applied research. This may result into an untidy organization which, from the standpoint of achieving results, was immaterial. The danger of rapid expansion of a scientific organization lay in the recruitment of undesirable persons who, once recruited, would camp on their jobs for a number of years and might thereby seriously retard healthy progress.

(*b*) Objective-applied scientific research could yield the best results when correlated with the tried empirical knowledge in the country with immediate, near-future and distant-future requirements.

(*c*) Fundamental scientific research should be fostered and encouraged in universities, private institutions and societies by making adequate financial provisions. This would ensure continuity of research and development through the provision of trained men for the government research and development departments.

(*d*) In the early stages of training, it was necessary to acquire a thorough knowledge of local problems and local resources and therefore it will be advantageous if training up to doctorate degree were imparted in the country of origin of the person. In this connexion, I.C.I. Fellowships and National Fellowships recently instituted in India will go a long way in stimulating research in Indian universities and scientific institutions. Training abroad could comparatively be most helpful in developing the resources of a country if the person to be trained were fully familiar already with the needs and requirements of this country.

(*e*) Expert advice was often sought in matters of planning and development of local resources. In the case of agriculture, animal husbandry, fisheries, forests and other biological sciences, an ' expert ' should not only possess technical knowledge and skill, but must also have a thorough grasp of local conditions. So when an ' expert ' goes out to a new country, he will do well not to advise until he has gained sufficient local experience of physical, biological and human factors in the new environment. Technical knowledge is no substitute for local experience.

(*f*) There can be no question that interchange of scientists will lead to an even and intensive development of all parts of the Commonwealth, but so far as possible the deputation of individuals should be for a period of one year at least so that an all-season idea could be formed of the country receiving the scientist.

Dr C. J. MACKENZIE (*Organization of Research in Canada*)

In 1917 the newly established National Research Council of Canada made a survey of research facilities and found them meagre, poorly financed and badly undermanned. Some research was being done by government departments and in universities and a little by a few commercial concerns, but the interest in research was low. Conditions have changed since then, and to-day Canada has greatly expanded facilities and staff, and the public interest in research has never been higher.

The development of research in industry in Canada has been slow, largely because many of our industrial concerns depend on their parent organizations in the United Kingdom and the United States for their research. Government research, on the other hand, has expanded rapidly, first, because of the necessity of speeding up the production of the raw materials which for many years were the basis of Canada's export trade, and second, because somewhat later, interest in the processing of these raw materials developed. There is therefore an historical reason for the fact that the Canadian Government departments most involved in research

are those whose duty it is to administer the development of natural resources. These are the Department of Agriculture, the Department of Mines and Resources and the Department of Fisheries (Chart No. 1).

The administrative portions of the Department of Agriculture are grouped in three services, administration, production service and marketing service, and the scientific background for their work is dependent on two other organizations, the Experimental Farms Service and Science Service. The Experimental Farms Service (Chart No. 5), operates a large Central Experimental Farm at Ottawa and a number of experimental stations in every province. The general functions of these stations are to develop improved methods of plant and animal production and to carry these methods to a point where they can be used by the farmer. The further function of keeping the farmer informed is also carried on by these stations. In connexion with this work, a considerable amount of detailed investigation and research is necessary, and the Central Experimental Farm is equipped and staffed to carry on a great deal of this type of work. The work is centred in divisions dealing with cereals, forage plants, field husbandry, fibre, animal husbandry, tobacco, poultry and bees. These divisions act in an advisory capacity in their fields to each of the experimental stations throughout Canada.

The Science Service of the Department (Chart No. 4), has Divisions of animal and poultry pathology, chemistry, botany and plant pathology, entomology, plant protection and bacteriology and dairy research. The service is responsible for the maintenance and development of the national collection of insects, the Dominion arboretum and an economic herbarium. It deals with the control of insect pests and diseases of plants and animals, the deterioration of plant and animal products by the action of fungi and bacteria, the nutritional requirements of plants and animals, the chemistry of soils, foods and dairy products, and the inspection of imported and exported plants and food products for insect pests and diseases. Its work is so integrated with that of the other parts of the Department that a complete service from the laboratory to the field or factory is provided in conjunction with services linking the producer with the ultimate consumer.

The Department of Mines and Resources (Chart No. 3), is a somewhat heterogeneous collection of services dealing with such diverse topics as lands, parks and forests, mines and geology, surveys and engineering, Indian affairs and immigration. The Immigration Branch is purely administrative, and the Indian Affairs Branch largely so. However, the latter is responsible for the welfare of this native people and, in consequence, has been involved in nutritional research in collaboration with the Department of National Health and Welfare.

The Lands, Parks and Forests Branch operates the Dominion Forest Service and the Forest Products Laboratories. The Dominion Forest Service has an active interest in silvicultural research, and a programme is being carried out in co-operation with the National Research Council under an associate committee. The investigations deal with the treatment of seedlings and cuttings, the development of strains of white pine, resistant to weevils and blister rust, and of poplar suitable for match stock and prairie shelterbelt planting. The development of rapid growing spruce for the pulp

industry is also being studied. The Service has taken an active interest in forest protection, particularly in the determination of the degree of forest-fire hazard.

In the Forest Products Laboratories problems dealing with the processing and utilization of wood are investigated. These include timber mechanics, wood preservation, chemistry of wood, timber pathology and timber physics. The laboratories have branches in Vancouver and Montreal, and the latter branch is a part of the Pulp and Paper Research Institute of Canada.

The Pulp and Paper Research Institute is supported jointly by the Dominion Government, the Canadian Pulp and Paper Association and McGill University. The chief effort of this institution is spent on fundamental and applied research. Ordinary testing work is carried out in the appropriate division of the Forest Products Laboratories. Among other projects, the Institute is working on the determination of the structure of lignin and on the validation of a theory of its nature and economic behaviour that was developed in the Institute. Work is also under way on the measurement of the colloidal surface of cellulose and the mechanism of its oxidation.

A large proportion of the research conducted in the Department of Mines and Resources comes under the Mines and Geology Branch, in which research is conducted in the Bureau of Mines, the Bureau of Geology and Topography and the National Museum of Canada. The Bureau of Mines has during the last decade become extremely well equipped for its tasks in obtaining and making available information on the mineral resources of the Dominion. The Bureau is responsible for mineral, metallurgical and fuel research and carries out mineral dressing, extractive metallurgy and other phases of work on minerals basic to plant practice. In its up-to-date physical metallurgical laboratories, the Bureau carries on work on corrosion and its prevention, foundry research, heat treatment, fatigue and stress and strain, and welding. It is the only laboratory in Canada at present equipped to work on gases in metals. It also possesses the only machine for shot-peening work in Canada. During the war a special Minerals Projects Division of the Bureau carried on exploration and development work on strategic minerals, and financed some university research in this field. In the fuel laboratories, research is conducted on oils, gases and solid fuels. This includes coal analysis and classification and studies in hydrogenation.

The National Museum, in addition to maintaining a collection of the mammals and birds of Canada, conducts biological studies, including ornithology and botany, in various localities when such studies are deemed necessary or advisable. Projects in archaeology and anthropology are also worked on by the Museum staff.

The Bureau of Geology and Topography is responsible for the discovery of mineral resources and the study of the nature and extent of underground water resources, and for the services for ground and air mapping. As a result of the latter duty, the Bureau has co-operated with the National Research Council and the Royal Canadian Air Force on problems associated with air photography for mapping purposes.

Dominion observatories located at Ottawa and Victoria B.C., carry on

the usual routine functions of observatories and are interested in astrophysics, photometric-photometry and terrestrial magnetism. A chain of teleseismic seismographs is maintained and short-period seismographs are in service at three points in connexion with mine rock-burst research. There is also a special study of earthquakes originating in Eastern Canada and the New England States.

The Department of Fisheries is fundamentally an administrative department and its research is carried out by the Fisheries Research Board of Canada, whose functions are outlined in detail in a paper that will be presented to the Conference. The Board, which consists of nine scientists, four representatives of the fishing industry and two representatives of the Department of Fisheries, is responsible to the Minister of Fisheries through whom its funds are obtained, but it conducts and finances research on its own responsibility. It operates a Marine Biological Station and a Fisheries Experimental Station on each coast, a Fisheries Experimental Station at Grand River, Quebec, and a central Fisheries Biological Station at Winnipeg. The coastal stations, including that at Grand River, deal with the many biological and processing problems that arise in a large industry dependent on the sea fisheries. The station at Winnipeg deals at present with technical problems in the inspection of commercial fish. The permanent staff of the Board numbers more than eighty, of whome forty-three are scientists.

The Board supplies fundamental information for the development of Canadian fisheries and the processing of the products. In connexion with its work in foodstuffs the Board collaborates with the National Research Council and the Dominion Department of Agriculture through the Associate Committee on Food Preservation.

The Department of National Health and Welfare is not organized primarily for research, but nevertheless some research is carried out in the Food and Drug Laboratory and in the Laboratory of Hygiene, in addition to the usual routine work. Close co-operation exists between this Department and the National Research Council. The Department has been represented on the Council's Associate Committee on Tuberculosis, and the National Research Council is represented on the National Council of Nutrition and the Advisory Council on Industrial Hygiene. There is very close contact between the laboratories of the Department and the Council's Divisions of Applied Biology and Chemistry.

The National Research Council (Chart No. 2), was set up by an Act of Parliament and is a body corporate, not associated with any particular Department of Government, but reports to a committee of the Privy Council on Scientific and Industrial Research which is composed of six ministers of the departments most intimately interested in research matters. The Honorary Advisory Council consists of fifteen members, the majority of whom have always been senior scientific members of university staffs with the minority representing industry, business and finance. The President of the Council is Chairman of the Honorary Advisory Council and is also the chief executive officer responsible for administering the overall activities of the Council. The National Research Council of Canada was set up to stimulate, conduct and co-ordinate scientific and industrial research, and was brought into being at approximately the same time as the Department

of Scientific and Industrial Research of Great Britain, and in a general way, functions very much as that Department does.

At present the Council has Laboratory Divisions of biology, chemistry, mechanical engineering and physics. These divisions are the continuation of the original structure but developments during the last few years have necessitated additions ; for example, a new Medical Division is being organized, and the Electrical Engineering and Radio Laboratories have become a separate Section under an officer-in-charge. The latter change was made as a result of the tremendous developments in electronics since 1939. Also the Atomic Energy Laboratory at Chalk River and the new Prairie Regional Laboratories at Saskatoon will operate essentially as Laboratory Divisions.

The Division of Biology operates laboratories dealing with bacteriology, biochemistry, refrigeration, fermentation and other subjects. The Chemistry Laboratories are equipped to deal with most phases of pure and applied chemistry and chemical engineering, and the Mechanical Engineering Laboratories deal with aerodynamics, hydrodynamics, instruments, engines and their fuels and structures, particularly with reference to aircraft. The Physics Laboratories are set up to deal with acoustics, radiology, metrology, optics, electrical measurements, heat and general physical problems. All of these divisions are in close contact with one another and with government departments, industries and universities interested in their various fields of research.

Researches conducted in the divisions may arise as the result of suggestions made by their own staffs, or in reply to requests from the government, or from any of its departments. Much of the research that has a bearing on the work of other government departments and industry is conducted through associate committees, a type of organization that possesses particular interest, and to which some attention shall be given here.

Almost at its inception the National Research Council decided that the welfare of research in Canada would depend on its efficiency and that efficiency could be obtained by bringing together wherever possible those best equipped to make suggestions as to the conduct of research. In order to bring these individuals together the system of associate committees was set up. Each committee acts as an autonomous unit. It may receive a grant from the Council or assistance from other sources, but it is at complete liberty to utilize the funds in accordance with its discretion. The Council looks after the administrative details and the committee outlines the researches, decides in which laboratories they should be conducted and gives consideration to the results.

The operations of committees may perhaps be better understood if a few examples are given. The Committee on Aeronautical Research is representative of the National Research Council, the Royal Canadian Air Force, the Department of Transport, the Air Transport Board and the aviation industry. During the war its functions had to do largely with developments of aircraft for training or fighting purposes. In peacetime it will turn its attention to developments in passenger and freight transport, and to fundamental studies in aeronautics generally.

The Committee on Food Preservation is a joint organization sponsored

by the National Research Council, the Department of Agriculture and the Fisheries Research Board. It originated from a desire to improve the condition of foodstuffs, particularly meats, that were being shipped to Great Britain, but problems have been brought to its attention that involve fruits, eggs, poultry and other food products, with the result that the committee is now involved in work of dehydration, refrigeration in transport and in storage, and packaging, including gas-tight packaging. In the work of the committee, the Department of Agriculture and the National Research Council have divided a number of the problems between them, and the Fisheries Research Board, which carries on its own researches in these fields as far as fish is concerned, reports to the committee and takes part in the discussions of the work done by the other sponsors. As a result, progress made in the dehydration of one product may soon lead to similar progress in the dehydration of a quite dissimilar product. In addition, progress in the refrigeration of meat is obviously of importance in connexion with the fish industry. The work of this committee was of tremendous importance during the war, particularly in the development of cheap methods of refrigeration for use in non-refrigerated ships, and in the dehydration of foods.

The Fisheries Research Board and the National Research Council sponsor the National Committee on Fish Culture, which deals with research in certain sections of the fisheries field which were not completely covered by the Department of Fisheries and the Fisheries Research Board. These include studies of fish culture, the growth and development of fish in inland waters, the stocking of lakes and rivers and studies of the biological conditions in lakes in various parts of the country.

At present there are forty-two associate committees and a hundred sub-committees working on a number of topics and having in their combined membership representatives of universities, industry and every government department.

The associate committees have provided a most efficient means of making use of scientific talent in institutions throughout the country. Many research projects are carried out in university laboratories by members of the staff and graduate students, thus enabling more complete use to be made of the equipment and staff available, and at the same time training young scientists in the universities. The small grants which are made by the committees enable competent research directors to plan for wider programmes, and stimulate research in even the smallest universities and departments.

An associate committee that had a somewhat different history from most of the others was the Associate Committee on Medical Research. This was set up some years before the war with the object of co-ordinating and stimulating medical research in Canada. Under its first chairman, Sir Frederick Banting, the committee found itself faced with a multitude of service problems at the beginning of the war. These added vastly to the committee's work and as a result, a series of committees representing the different services and their needs were set up. Finally a large number of sub-committees on specific subjects had to be organized. The work of all of these was correlated by a Steering Committee, whose chairman was Dr J. B. Collip. As a result of the effectiveness of the work of this com-

mittee, it has now been decided to set up a Medical Division of the National Research Council.

A special type of associate committee is that which is organized on behalf of an industry which has approached the Council for the solution of certain of its problems. In these cases the committee is formed to act in an advisory capacity. The industry brings its problems to the committee where they are discussed and the research programme is outlined. The industry provides the financial backing for the work, including the payment of staff. An example of this type of committee is the Associate Committee on Asbestos, which operated until 1939, at which time the industry took over the research itself, but the industry still looks to the committee for guidance on occasion. Another example of this nature was the Associate Committee on Magnesian Products, whose work was to devise ways and means of utilizing to better advantage large Canadian deposits of rock containing magnesia. This work, undertaken by direction of the Government and prosecuted with the financial support of the co-operating companies, was so successful in the development of high-class refractories and related products that to-day Canada, instead of being an importer, is an exporter of large quantities of these materials.

The appointment of an Associate Committee on Laundry Research resulted in the establishment of the Canadian Research Institute of Launderers and Cleaners, which now supports the laundry research carried on at the National Research Laboratories. More than one hundred laundries in all parts of Canada receive the benefits of a research and checking programme carried on in the laboratories.

In addition to grants given in aid of research by associate committees, the Council makes direct grants for research on subjects which are not covered by any associate committee. Such grants are given only to scientists of repute who have available the normal laboratory equipment. Grants may be used for the payment of assistants or for the purchase of equipment that would not be ordinarily found in the type of laboratory concerned. The grantee receives no direct monetary reward.

Another means by which the Council promotes research is through scholarships, which are given to postgraduate students in the sciences. These scholarships are held in university laboratories, and while much of the work done under them may be of an elementary nature, in the mass it provides for considerable progress in science, while it trains a corps of junior scientists.

Because of the size of the country and the differences in its natural products, the interests of the Council have to be wide enough to take in the miscellaneous studies that must be undertaken on diverse types of resources. It has been found desirable recently, to set up at Saskatoon on the Canadian Prairies, the first regional laboratory, for the study in this case of the utilization of farm products or wastes. This laboratory will operate for the time being as a sub-division of the Division of Applied Biology, and its main tasks will lie in the fields of fermentation, process development, utilization of straw and the production of vegetable oils.

The extensive research and development work carried on in Canada in connexion with atomic energy has been under the administrative direction of the National Research Council, and it is expected that when

the proposed legislation now before the Canadian Parliament in connexion with the overall control of atomic energy is passed, the Research Council will be asked to assume responsibility and direction of all laboratory and development work carried on in Canada in the future.

Before the outbreak of war the Council had close contact through its associate committees, research grants and scholarships, with universities and other laboratories throughout the country, but its contacts with organizations outside the country were taken care of without any particularly definite organization. After the outbreak of war the flow of secret and confidential information to and from Canada necessitated the setting up of a special channel. The Council therefore set up liaison offices in Ottawa and in London, and later in Washington. These offices have carried on an active exchange of information, originally of a classified nature, but now including information on all sorts of scientific matters not normally considered confidential. This service has provided laboratory workers with outside contacts which they would find difficult to make as individuals, and has facilitated the obtaining of literature and equipment necessary for the efficient operation of the laboratories. The fact that every department of government was involved in Canada's war effort has made the liaison offices strong bonds of union between the National Research Council and other government departments, including of course the service departments.

Before the war, there was no organized programme of military research carried on by the Department of National Defence. The National Research Council on behalf of that Department did, however, conduct a limited number of investigations in ballistics, radio and chemical warfare. When the war broke out, the Council was officially named the research establishment of each of the three services, and from that time till the end of the war, the Council's activities were almost exclusively devoted to military problems. Additional laboratories were built, staffs were increased by almost tenfold and the resources of the universities, industries and other government laboratories were co-ordinated under Council supervision. With the end of the war, the Government decided that military research must be continued in the future and a sub-division of the Department of National Defence was created under a Director-General of Research and Development who will have supervision over all research in the three armed services. The Director has the rank and standing of a Chief of Staff and is a full member of the Chiefs of Staff Committee. The newly appointed Director is presently engaged in working out the future plans of the Division and while no definite decisions have yet been reached, it is expected that there will be strong liaison between that Division and the National Research Council in certain fields of research.

Research in the universities in Canada has followed, in the main, the traditional pattern found in the graduate schools of the Commonwealth. It has been largely fundamental in character, but in certain sections a great deal of research has been carried out in connexion with the basic problems of the locality. The universities co-operate with Dominion Government Departments, Provincial Government Departments and the National Research Council in research on most of the natural resources. In addition to university research some provincial research organizations have been set

up, their functions being outlined fairly definitely either by the provincial government or by its co-operating sponsors.

The Province of Alberta set up a Scientific and Industrial Research Council in 1921. The scope of its work was not outlined in detail, but mention was made of the necessity of promoting mineral development within the province. This Council operates under an act somewhat similar to the act setting up the National Research Council of Canada and it is financed by provincial government appropriations. Its investigations include the study of the coal resources of the province, the bituminous sands of the Athabasca region, geological and soil surveys and studies of the natural gases. During the depression years the Council's work was restricted, but it continued in a modest way with the study of the coal resources of Alberta. At present the Council's greatest handicap is a shortage of staff to handle the amount of work waiting to be done.

The Council is located at the University of Alberta and operates in close co-operation with the science departments of that institution, some of its members being on the university staff.

The most recent provincial research organization is the British Columbia Industrial and Scientific Research Council, which was set up in 1944 to deal with the provincial problems of British Columbia in its primary and secondary industries. The Council hopes to make surveys as a basis of new production from untapped sources and to encourage the processing of raw materials wherever research indicates economic possibilities. The Government is interested in trade expansion programmes and hopes that the results of the researches to be undertaken will provide at least some new secondary industries. The members of the Council are specifically charged with bringing to the Council's attention the problems of industry, and the Council is expected to act as a clearing house for supplying technical assistance and advice to industries in British Columbia.

The Ontario Research Foundation was established by the Ontario Legislature in 1928 and is financed by an endowment fund composed of subscriptions received over a period of years from manufacturers, corporations, private individuals and by a grant from the Provincial Government on a dollar per dollar basis with the other contributions. The Foundation carries on research to assist agriculture and industry and to develop the natural resources of the province. Most of the investigations that have been carried out have been in the industrial field and the Foundation is well equipped to work in metallurgy, textiles and chemistry and biochemistry. The services of the Foundation are at the disposal of industries on a cost basis, and consultative services, testing, short trial studies and long term investigations have been undertaken for hundreds of Canadian firms. The work has resulted in better products and more efficient processing.

During the war the Foundation was a very important part of the research arm of the Canadian industries and the services.

In the textile field work on rayon knitted materials has been expanded until practically every type of fabric based on rayon is included. The development of dye formulae has been important and the production of dyed fabrics with special resistance to sunlight has occupied considerable effort. In chemistry a number of problems in the food industry and in the

gas industry have been under investigation, and problems associated with the utilization of by-products of the paper industry have also been attacked. An investigation of domestic linseed oil has been carried out in co-operation with the Committee on Food Preservation of the National Research Council. The object of the investigation has been to produce a shortening composed of hydrogenated linseed oil in a plastic state which could withstand storage and heating without developing the characteristic offensive odour.

Another research organization in Ontario is the Banting Research Foundation, which was set up in the year 1925 and authorized to provide financial assistance to the Banting and Best Chair of Medical Research in the University of Toronto and to individual scientific workers elsewhere who might propose suitable problems of medical research. The Foundation has expended a large sum of money on grants ranging usually in amount from $100 to $1,800. Assistance may be given to provide apparatus, supplies or living expenses. The applicant is expected to propose a definite problem in medical research of such a nature that with the facilities available, reasonable progress towards the solution of the problem may be expected during the tenure of the grant.

An act to set up a Research Foundation in Nova Scotia was presented to the legislature of that province in March of this year. The structure of the Foundation is similar to that of the National Research Council and its functions are to promote knowledge and utilization of the natural resources of the province, and to undertake a variety of researches aimed at the development of these resources, the improvement of the quality of the products therefrom and the discovery of uses for the waste products of industry. The Foundation will have power to supervise research on behalf of single industries or groups of industries and may enter into financial agreements to do research or to have it done. It is the intention to build and staff laboratories for these purposes.

The fact that there are few provincial research organizations in being does not indicate a lack of interest in research in the provinces. It must be remembered that provincial governments in most cases have the university laboratories to call upon and this applies particularly in connexion with local industrial and agricultural problems. Agriculture is particularly well looked after because of its great importance as an export industry, and the network of Dominion Department of Agriculture laboratories and experimental stations, together with the agricultural colleges and the few provincial research councils, provides this industry with a very well developed research service.

While there is an awakening interest in research in Canadian industry, compared with the situation in the United Kingdom and the United States, we have few industrial laboratories, but, for reasons already stated, this does not mean that Canadian industry is completely cut off from research, as the nearby facilities in the United States have in the past been available to many of the larger Canadian firms. Most small industries and many large ones in Canada have in the past been totally unaware of the value of research to their industries and to the country. This has been serious for industry, but it has another unfortunate side in that many of the best young scientists have been attracted to other countries because they found that positions were scarce and the emoluments smaller in Canada. Part of this

difficulty is due to the fact already mentioned that many Canadian companies are subsidiaries of companies in Great Britain and the United States ; part of it to the fact that small industrial companies find it impossible to finance their own research laboratories.

To meet these conditions, the National Research Council undertakes to co-operate with industry in any one of several ways ; by individual agreements on the ' Melon Institute ' plan, by organizing associate committees and by co-operating with ' Trade Associations ' under arrangements similar to the Research Association scheme of D.S.I.R. This latter type may well develop extensively in the future, but the Canadian solution of this general problem, which we all recognize, must always be approached with an understanding of the local picture of enormous areas, absence of concentration of similar industries and proximity to the vast research facilities of the United States.

CHART NO. 1

CANADIAN DOMINION GOVERNMENT RESEARCH ORGANIZATIONS

CABINET

Minister of National Defence	Minister of Fisheries	Minister of Agriculture	Privy Council Committee on Scientific and Industrial Research (Six Ministers)	Minister of Mines and Resources	Minister of National Health and Welfare
			Honorary and Advisory Committee on Scientific and Industrial Research		
Director of Defence Research	Deputy Minister	Deputy Minister	President	Deputy Minister	Deputy Minister (Health)
National Defence Department	Fisheries Department	Agriculture Department	National Research Council	Mines and Resources Department	National Health and Welfare Department
Directors of Defence Research	*Fisheries Research Bd.* Central Fisheries Research Stations Three Experimental Fisheries Stations Two Biological Stations	*Science Service* *Six Major Divisions* *Central Experimental Farm* Eleven Major Divisions Illustration Stations Experimental Stations *Major and Minor Sub-Stations* Prairie Farm Rehabilitation (Details in Charts No. 4 and 5)	Biology Division Chemistry Division Mechanical Engineering Division Medical Division Physics Division Electrical Engineering and Radio Branch Prairie egional Laboratory Atomic Energy Laboratory and Plant Associate Committees Extramural Groups Patents and Independent Agreements Codes and Specifications (Details in Chart No. 2)	Bureau of Geology and Topography Bureau of Mines Dominion Observatories Dominion Forest Service Forest Products Laboratories Medical Service National Museum (Details in Chart No. 3)	*Health Branch* Food and Drug Laboratory Laboratory of Hygiene Industrial Hygiene Laboratory

CHART NO. 2

NATIONAL RESEARCH COUNCIL, CANADA

COMMITTEE OF PRIVY COUNCIL ON SCIENTIFIC AND INDUSTRIAL RESEARCH

HONORARY AND ADVISORY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
A body corporate

PRESIDENT OF COUNCIL, CHAIRMAN AND CHIEF EXECUTIVE OFFICER

VICE-PRESIDENT, ADMINISTRATIVE
Administrative Matters

VICE-PRESIDENT, SCIENTIFIC
Scientific Matters

DIRECTOR EXTRAMURAL ACTIVITIES

Library, Journal and Publications Officer in Charge

Univ. Exch. Comm. Honorary Chairman

Scholarships Comm. Honorary Chairman

Comm. on Grants-in-aid-of-Research Honorary Chairman

Scientific Liaison Officers

DIRECTOR
Biology Laboratories

Bacteriology
Biochemistry
Refrigeration
Fermentations
Polysaccharides
Animal Fats
Biometrics

DIRECTOR
Chemistry Laboratories

Inorganic Chemistry
Organic Chemistry
Physical Chemistry
Applied Chemistry
Chemical Engineering
Textiles
Customs and Excise

DIRECTOR
Mechanical Engineering Laboratories

Aerodynamics
Instruments
Engines and Gas Dynamics
Hydrodynamics
Structures
Gasolines and Oils
Low Temperatures

DIRECTOR
Physics Laboratories

Acoustics
Radiology
Metrology
General Physics
Optics
Electrical Measurements
Heat

Patent Corporation
Patents and Industrial Agreements

New and Special Projects

Officer in Charge
Codes and Specimens
(Nat. Bldg. Code, Etc.)

DIRECTOR
MEDICAL DIVISION

Advisory Medical Committee
Co-operative Projects
Grants-in-Aid
Scholarships

OFFICER IN CHARGE
PRAIRIE REGIONAL LABORATORIES

Fermentations
Process Development
Straw Utilization
Vegetable Oils

SECRETARIAT
ASSOCIATE COMMITTEES

Aeronautical Research
Canadian Government Pur. Standards
Explosives
Food Preservation
Industrial Radiology
Laundry
Survey Research
and
135 others, comprising
42 Committees and
100 Sub-Committees

OFFICER IN CHARGE
ELECTRICAL AND RADIO ENGINEERING LABORATORIES

Electrical Engineering
Cathode Ray Direction Finding
Ionosphere
Radio and Radar

DIRECTOR
ATOMIC ENERGY PROJECT
Chalk River Laboratory

Chalk River Pile and Pilot Plant

CHART NO. 3

DEPARTMENT OF MINES AND RESOURCES

Minister

Deputy Minister

Secretary and Chief Executive Assistant

Director	Director	Director	Director
Lands, Parks and Forests Branch	**Mines and Geology Branch**	**Surveys and Engineering Branch**	**Indian Affairs Branch**
Dominion Forest Service	*Bureau of Mines*	Dominion Observatories	Medical Service
Forest Products Laboratories	Mineral Metallurgical and Fuel Research	Engineering and Construction Service	
	National Museum of Canada Botany and Biology	Hydrographic and Map Service	
	Bureau of Geology and Topography	Dominion Water and Power Bureau	
		Geodetic Service of Canada	

CHART NO. 4

DOMINION DEPARTMENT OF AGRICULTURE
SCIENCE SERVICE

DIRECTOR

ADMINISTRATIVE DIVISION

DIVISION OF ANIMAL AND POULTRY PATHOLOGY

- Animal Pathology
- Poultry Pathology
- Biological Products
- Parasitology
- Laboratory Services
- 3 Branch Laboratories

DIVISION OF BOTANY AND PLANT PATHOLOGY

- Agricultural Botany
- Systematic Botany
  - Arboretum and Herbarium
- Mycology
- Forest Pathology
- Cereal Diseases
- Fruit and Vegetable Diseases
- Seed-borne Diseases
- Plant Physiology
- 12 Branch Laboratories

DIVISION OF ENTOMOLOGY

- Field Crop Insect Investigations (7 Branch Laboratories)
- Forest Insect Investigations (7 Branch Laboratories)
- Fruit Insect Investigations (5 Branch Laboratories)
- Systematic Entomology
- Parasitic Insect Investigations
- Livestock Insect Investigations
- Stored Product Insect Lab.'s

DIVISION OF BACTERIOLOGY AND DAIRY RESEARCH

- Dairy Research
- Food Microbiology
- Soil Microbiology
- General and Analytical Bacteriology

DIVISION OF CHEMISTRY

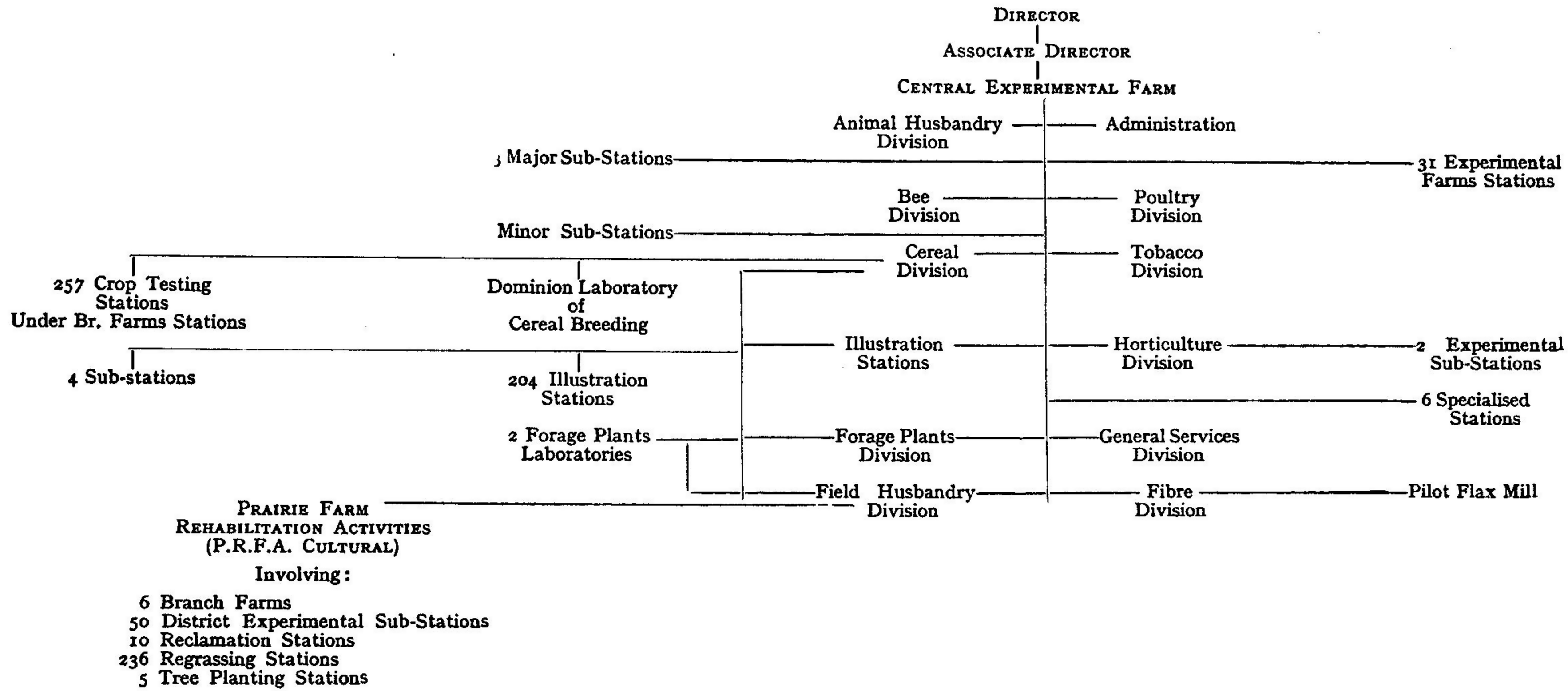
- Food Chemistry
- Soil Chemistry
- Animal Nutrition
- Plant Chemistry
- 3 Branch Laboratories

DIVISION OF PLANT PROTECTION

- Plant Inspection
- Seed Potato Certification

CHART NO. 5

CANADA
DOMINION DEPARTMENT OF AGRICULTURE
EXPERIMENTAL FARMS SERVICE



Sir EDWARD MELLANBY (*The Medical Research Council*)

A large part of the medical research in this country is associated in one way or another with the Medical Research Council. The work of the Council is not only directed to the increase of knowledge for the prevention, diagnosis and treatment of disease, but also for the maintenance of full normal health in human beings. Much attention is also given to the development of the sciences—physiology, biochemistry, pharmacology and pathology—upon which medicine is based.

The Medical Research Committee was established in 1913 under the National Health Insurance Joint Commission to administer funds which were at that time provided by the National Health Insurance Act of 1911. By that Act a penny per insured person per annum was set aside for medical research, and the fund so raised amounted to a sum of the order of £40,000 to £50,000. Soon after the Committee started work the first great war broke out, an incident which might well have ended an enterprise of this kind but, far from this being the case, the war acted as a stimulus and the energies of the research organization were largely directed to help elucidate medical problems of war. This was a vast field and offered an opportunity for investigation, of which great advantage was taken.

In 1919 the Government decided to expand the organization and established the Medical Research Council, with a Royal Charter of incorporation and funds granted directly from the Treasury in the form of a parliamentary grant-in-aid. At the same time the Council became subject to the general direction of the new Committee of the Privy Council for Medical Research, consisting of the Lord President as Chairman and the Ministers in charge of the principal departments concerned with questions of public health at home and overseas. The Lord President became the Minister responsible to Parliament.

The Council now consists of twelve members, nine of whom represent different branches of curative or preventive medicine and the fundamental sciences upon which these are based. Of the remaining three, one must be a member of the House of Lords, one a member of the House of Commons, while the third, the treasurer, is a banker. The Council is not merely an advisory body but has full executive control of its funds, and in its scientific discretion is able to pursue an independent policy for the advancement of knowledge towards the relief of human suffering. In promoting medical research it is unrestricted by territorial or departmental limitations of function and its work is unhampered by claims of administrative or political expediency, although it works in close association with those government departments which are concerned with problems of public health.

The Council has one large institute of its own, the National Institute for Medical Research at Hampstead. No clinical research is done at the Institute, but most of the work is directed to the study of the basic sciences of medicine which include physiology, pharmacology, pathology and bacteriology. A good deal of research is also done on problems of chemotherapy, and the Institute is one of the two international homes for the standards of drugs and other biological products. Standards set up by the League of Nations and by the British Government in the medical field

are held at the National Institute, e.g. antitoxins, hormones, vitamins and other biological substances such as penicillin. The adoption of international standards of this kind has involved a large amount of co-ordinated investigation among workers in different countries and in this work the Medical Research Council has played a leading part.

What has now become the largest division of the Medical Research Council's work is concerned with the establishment and development of units of research in universities and hospitals. These are scattered all over the country and there are now about twenty-seven of them. The policy was started by the establishment of a Department of Clinical Research under Sir Thomas Lewis at University College Hospital in about 1919. Since then, and especially in recent years, there has been a large expansion of this type of organization. Some of these are as follows :

Department of Clinical Research, University College Hospital Medical School, London, W.C.1. (Dr E. E. Pochin).
Clinical Research Unit, Guy's Hospital, S.E.1. (Dr R. T. Grant).
Neurological Research Unit, National Hospital for Nervous Diseases, Queen Square, W.C.1. (Dr E. A. Carmichael).
Otological Research Unit, National Hospital for Nervous Diseases, Queen Square, W.C.1. (Dr C. S. Hallpike).
Radiotherapeutic Research Unit, Hammersmith Hospital, W.12. (Dr Constance Wood).
Electro-Medical Research Unit, Stoke Mandeville Hospital, Aylesbury. (Dr R. B. Bourdillon). In process of formation.
Experimental Medicine Research Unit, University of Cambridge. (Professor R. A. McCance).
Human Nutrition Research Unit, National Hospital for Nervous Diseases, Queen Square, W.C.1. (Dr B. S. Platt).
Dunn Nutritional Laboratory, University Field Laboratories, Cambridge. (Dr L. J. Harris).
Group for Research on Nutrition, Lister Institute of Preventive Medicine, S.W.1. (Dr S. S. Zilva).
Bacterial Chemistry Research Unit, Lister Institute of Preventive Medicine, S.W.1. (Sir Paul Fildes).
Group for Research in Chemical Microbiology, University of Cambridge. (Dr Marjory Stephenson).
Cell Metabolism Research Unit, University of Sheffield. (Professor H. A. Krebs).
Burns Research Unit, Birmingham Accident Hospital, Birmingham. (Dr L. Colebrook).
Industrial Medicine Research Unit, Birmingham Accident Hospital, Birmingham. (Dr J. R. Squire).
Department for Research in Industrial Medicine, London Hospital, E.1. (Dr D. Hunter).
Pneumokoniosis Research Unit, Cardiff. (Dr C. M. Fletcher).
Unit for Research on Dental Disease, King's College Hospital, London. (Dr J. D. King).
Group for Research in Industrial Physiology, London School of Hygiene and Tropical Medicine, W.C.1. (Dr T. Bedford).

Applied Psychology Research Unit, University of Cambridge. (Professor F. C. Bartlett).
Group for Research in Industrial Psychology, University of Manchester. (Dr S. Wyatt).
Group for Statistical Research, London School of Hygiene and Tropical Medicine, W.C.1. (Professor A. B. Hill).
Blood Products Research Unit, Lister Institute of Preventive Medicine, S.W.1.
Blood Grouping Research Unit, Lister Institute of Preventive Medicine, S.W.1. (Dr R. R. Race).
Central Public Health Laboratory, Colindale Avenue, The Hyde, N.W.9. (Dr R. Cruickshank).
National Collection of Type Cultures, Lister Institute of Preventive Medicine, Elstree, Herts.

The formation of a unit of research first involves the choice of an able leader as director. After appointment he is free to pick his own team and select the necessary equipment for research and, within his field, he is encouraged to open up the subject to the best of his ability. Sometimes a unit of research is established by the Medical Research Council because it is obviously desirable to give a particular research worker the best chance to use his talents. Sometimes, however, it is the subject of research which demands attention and then the best available man is chosen as director of the unit and asked to work in the new field. This method has the great advantage of keeping able investigators and their teams within universities and hospitals, where they are encouraged to take some part in the instruction and care of patients. These institutions can in turn feed promising young students into the units for research experience. The research unit or department is only established for the period of office of the director but, if there is an obvious successor, the unit continues with change of director. There is nothing static or permanent about this scheme of research.

The third method by which the Medical Research Council helps medical research is by giving grants to individual workers in universities and hospitals. In this case the initiative comes from the actual worker or from his professor. Each grantee presents his programme of work and, on the merits of the programme and of the applicant, grants are awarded or withheld. At any time there may be as many as 300 grants of this kind and a wide net is thus thrown over the medical research field.

Each of these three schemes of research has its own merits and allows the development of subjects under investigation by different groups of people working under different conditions. It might be asked which of the schemes, in the experience of the Medical Research Council, is more likely to lead to or play an important part in discovery. It is difficult to answer this question, especially as the unit system, except in a few instances, has not been long in action. In the thirty-three years' life of the Council, each of these research systems has had its triumphs. In the case of the National Institute for Medical Research we have had such important discoveries as (1) the chemical transmission of the nervous impulse and (2) the isolation of the viruses of influenza and distemper. In the unit scheme the sulphonamides were established as important therapeutic agents when the mortality rate of puerperal septicaemia was brought down from 25 per cent to about

5 per cent, and later a new chapter in sulphonamide chemotherapy was opened when para-aminobenzoic acid was shown to be a controlling factor in their action on micro-organisms. In the case of the research grant scheme there resulted (1) many of the leading facts concerning the relation of diet to rickets and to bone and teeth structure and (2) the isolation of penicillin and the experimental and clinical demonstrations of its curative effects in streptococcal and other infections. These, of course, are only some of the highlights of discovery as regards the Council's work and each scheme had led to a very large volume of other knowledge.

As a government organization the Medical Research Council is only a small body. Its present annual expenditure on medical research is about £400,000 and it also runs the Public Health Laboratory Service started before the war, the staff of which is engaged in medical research in addition to its other duties, at an annual cost of about £100,000. The senior research staff consists at present of about one hundred permanent and one hundred temporary members ; many of the latter will become permanent members. The standard of the permanent research staff is high and of the one hundred members, fourteen are Fellows of the Royal Society. There are nineteen other Fellows of the Royal Society who have been permanent or temporary members of the staff. Some of these have retired from the Council's service, but the greater number are those who have returned to the universities after working for the Council. This movement is encouraged.

The Medical Research Council has wide interests in research outside this country. There is for instance the Colonial Medical Research Committee, half of which is appointed by the Colonial Office and half by the Medical Research Council. In the case of India also, there is a liaison committee on medical science, half appointed by the Indian Government and half by the Medical Research Council. These wide territorial schemes have the merit of allowing the Council to work in close association with colonial and other investigators as well of course as giving their own research staff the opportunity of working on tropical disease in addition to that of temperate climates. Thus, the machinery is in being whereby the Council can receive investigators from, or send them to, India or the Colonies.

It may be desirable at this Empire Conference to discuss the question of closer association in matters of medical research between the Dominions and this country. Those of us who are engaged in medical research usually know each other well and, indeed, it is a great pleasure to greet a number of our distinguished visitors from the Dominions at this Conference who have worked in this country earlier in their career. It may be that our friendship, which has allowed useful collaboration in the past, may also suffice in the future. On the other hand, it can be said with assurance that, if there is any desire for a more formal scheme of collaboration in medical research by our Dominion colleagues we, in this country, will welcome and do our best to work any such scheme.

Professor J. N. MUKHERJEE (*Scientific Organization relating to Agriculture in India*)

Professor J. N. Mukherjee supplementing the observations of Sir S. S. Bhatnagar said : Regarding the scientific organization relating to agriculture, apart from the organizations under the Central Government, each

province and several States have got departments of agriculture with experimental stations under them. Agricultural education has been a provincial subject up to the degree course. The provinces also deal with the extension of results of research. They are responsible for promoting the application of scientific methods by the peasants. Apart from the Imperial Agricultural Research Institute and its sub-stations which include the Coimbatore station for sugar cane breeding, there are two other institutes under the Central Government, namely the Imperial Institute of Veterinary Research at Izatnagar and at Mukteshwar and the Imperial Dairy Research Institute at Bangalore. The Agricultural Department has also under it a Forest Research Institute at Dehradun. The provincial governments have departments of forestry under them. The establishment of a number of other central research institutes is under contemplation. These will include a veterinary college and an agricultural college for the degree standard and are meant for provinces which have not these facilities. The central institutes are centres of both training and research. An organization for plant protection and quarantine service has been started by the Central Government. The Imperial Council of Agricultural Research which is also under the Central Government intends to maintain in addition to those mentioned by Sir S. S. Bhatnagar, several other central institutes, e.g. for paddy, potatoes, pulses and oilseeds. These institutes are under what are called commodity committees for a crop or a group of crops. Technological as well as agricultural aspects are dealt with by the institutes under these committees. The technological work is not under the Council of Scientific and Industrial Research but under the Imperial Council of Agricultural Research. Irrigation which is of great importance for Indian agriculture is not under the Agriculture Department either in the centre or in the provinces, but is dealt with by central and provincial irrigation departments. A Central River and Waterways Commission has recently been set up for dealing with the training of rivers, development of hydro-electric power, irrigation and drainage.

Colonel Sir SAHIB SINGH SOKHEY (*General Scientific Organization in India*)

The position of medical research in India is far from sound. The medical colleges of the Indian Universities do not generally engage in research, neither in the pre-clinical scientific subjects nor in the clinical subjects. These colleges were originally organized to produce assistants for the superior medical service recruited solely in the U.K. Young men soon after their graduation in medicine joined this superior medical service without any research training or experience. Until recent years the teachers for the medical colleges were drawn exclusively from the members of this medical service, with the result that research activity did not develop in these institutions.

Since the end of World War I, the character of the Indian medical colleges has begun to change, but research activity has still not become vigorous, or even mildly developed. At about the same time the Government of India created a fund under the Indian Research Fund Association to provide grants for medical research. This was to begin with a purely government body and was interested entirely in subsidizing research at the

four or five government laboratories which had been established in India to produce vaccines and other biological products needed by Public Health Departments.

More recently the composition of the governing body of the Association has been liberalized by the inclusion of non-officials, but in its character the Association is still highly bureaucratic and has not shown any real interest in developing research centres in the medical colleges. The over-all result is that the standard of medical education is not high, and research activity is very meagre.

Another extremely serious result of the bureaucratic outlook of the superior medical service has been that medical relief for the people is very poorly developed. Outside urban areas no serious attempt has been made to provide medical relief. The whole situation was so extremely unsatisfactory that the Government of India recently appointed a committee to investigate into the whole position and make recommendations to improve the situation. This committee, known as the Bhore Committee, has just issued its report. The report carefully describes the present position and makes valuable recommendations for improving the situation on a short term basis. It is a weighty document and it is hoped it will receive the serious attention of the Government. The improvement in the medical relief of the people brooks of no delay.

Mr D. N. WADIA (*General Science Organization in India*)

I have been asked to speak on the scientific academies and societies of India and the rôle they play in the organization of science in the country to-day. For a country so devoid of organized scientific research laboratories and institutions, these societies, struggling under many difficulties, financial and others, have during the last two or three decades done creditable work in spreading knowledge of science and in providing channels of communication and publication of whatever research is done. Compared to their European counterparts of course these societies cannot claim any considerable antiquity ; with the exception of the Asiatic Society of Bengal, which has a sesqui century behind it, of the Indian Association for Cultivation of Science, which is seventy years, and some of the Mathematical Societies of Poona, Benares, etc., and the Bombay Natural History Society, which are about sixty years old, few of our science associations are older than about forty years. These bodies are all unofficial, dependent on their own resources, largely members' subscriptions, and it is with difficulty that they have maintained their journals and publications and kept alive the spirit of scientific research.

The largest and best organized body is the Indian Science Congress, founded in 1913 by the Asiatic Society of Bengal. It has now a permanent membership of over 1,000. There are some thirty-five other societies dealing with physical, biological, geological, medical and social sciences. To co-ordinate the activities of these different bodies and to represent internationally the scientific work of India, the National Institute of Sciences was inaugurated in the year 1934. This Institute has grown in stature and has been recognized by the Indian Government as the premier scientific body in the country.

I might here allude to an unfortunate circumstance peculiar to Indian

science economics. It has been our sad experience that in periods of financial stringency, it is the scientific departments and grants to science which become the first casualties. Both our government and our politicians look to scientific departments, few as they are, as the very first to be axed for tiding over their difficulties. Few science organizations have escaped this treatment in the past and it is the scientific societies, independent of government finance, which kept working and kept the torch of science alight for the workers.

In this assembly of distinguished representatives of science from the different units of the Commonwealth, met for the purpose of scientific co-operation, I wish particularly to refer to the collaboration in science which can be achieved by a liaison between the science associations of different Empire countries. Indian science societies are very willing to participate in any scheme of mutual collaboration—interchange of publications, specimens, scientific material and preparations. The region of India, with its varied geographical and biological zoning has much to offer from its store of natural history, agricultural, forest and other organic and mineral raw materials. Also it has interesting 80 to 100 year recordings of magnetic, geodetic and isostatic data, highly characteristic and regional in nature. This Conference will achieve much if it inaugurates a system of close liaison between parallel scientific associations in the Empire countries.

FORESTRY AND FOREST RESEARCH IN CANADA

THE vast extent of the forested areas of Canada and the size and diversity of her forest industries together present forestry problems which are peculiar to Canada among Empire countries. Furthermore, the retention of title to most of the forests by the Crown, together with complete reliance on private enterprise for their exploitation, result in certain characteristics of Canadian forest administration which are unique not only in the Empire but in the world.

This conference of the Royal Society is particularly concerned with means of increasing collaboration between British countries with respect to the interchange of scientific knowledge. Such collaboration, if it is to be effective, must be based on a thorough appreciation of the nature of the co-operating authorities, and for this reason it seems profitable to review briefly the physical and administrative characteristics of Canadian forestry.

The forested area of Canada totals 1,291,000 square miles. Of this vast tree covered area, nearly 478,000 square miles are considered to be non-productive from a commercial point of view because of adverse site conditions which preclude the possibility of obtaining merchantable forest crops. Of 813,000 square miles of productive forest lands, it is estimated that 435,000 square miles are accessible to commercial operations while the remainder provides a reserve for the future which will be developed as transportation systems are extended.

Most of the population of Canada is distributed in a long narrow belt based on the boundary between Canada and the United States but varying somewhat in width from east to west. In the Maritime Provinces and in the south-western corner of British Columbia considerable concentrations of population occur within heavily forested regions but, in a general sense, it may be said that most of the population resides in the southern part of the Dominion while the main forest regions lie to the northward. This fact has a distinct bearing on the problems of forest administration.

In the nine provinces of Canada, which lie south of the 60th parallel of north latitude and contain approximately 2,000,000 square miles of land, about 58 per cent of the total area is covered by tree growth of one kind or another. This means that almost six acres out of every ten are forested, and in this computation the treeless areas of the great plains are included. In the North-west and Yukon Territories, which lie north of the 60th parallel and comprise about 1,500,000 square miles of land the forests are scattered and, although of great local value, do not contribute to Canadian commerce in forest products.

Canadian forestry industry is the third largest producer and the largest exporter of forest products in the world. It comprises more than 5,000 saw-mills and 108 pulp and paper mills in addition to many hundreds of miscellaneous woodworking plants. It provides employment equivalent to full-time work throughout the year for a quarter of a million people.

During the last year for which complete records are available, the net value of its products exceeded $600,000,000.

Canadian exports of forest products are shipped to more than 100 different countries and, because imports are relatively small, the forest industries in peacetime were a principal source of Canada's reserves of foreign exchange.

It is apparent from the brief résumé presented in the preceding paragraphs that forestry occupies a place of exceptional importance in the national economy of Canada and that forest conservation presents problems of vital importance to the nation. By its adherence to the constitution of the Food and Agriculture Organization of the United Nations, Canada has formally undertaken to develop its forests not only for its own purposes but also for the benefit of all mankind.

Organization of forest administration

In common with other natural resources, the Crown forests of each province are administered by the provincial government. Each province (except Prince Edward Island where there are no Crown forests) maintains its own forest authority. The forests of the North-west and Yukon Territories are administered by the Dominion Government through the North-west Territories Council. The Dominion Forest Service is not directly concerned with administration of forests, therefore its functions are discussed in a subsequent section of this brief which deals with the organization of forestry research.

Because of the great extent of continuous forested areas in Canada and the inflammable nature of the predominantly coniferous forests, the provision of protection against forest fires is always a principal problem of the Canadian forest administrator. With respect to the disposal of standing timber on Crown lands, he is guided by the general principle that ownership of the land itself must remain with the Crown. Rights to cut standing timber are granted to industry and to individuals under conditions which vary according to the size of the operation, the length of time for which it will require supplies, and the availability of supplies in the particular locality in which it is proposed to operate. Here it may be said that the multiplicity of forest authorities inevitably results in differences in details of regulations as between provinces ; nevertheless, the similarities which exist are much more remarkable than the differences.

Each provincial forest authority is responsible to a minister who is an elected member of the legislature and a member of the provincial cabinet. The minister is assisted by a deputy minister who is a civil servant and permanent head of the department. In every province the department responsible for forest administration has other duties to perform in connexion with lands or mines or other natural resources. In some cases a branch form of organization is used and the senior forestry officer is directly responsible to the deputy minister. In Quebec, separate services are responsible for forestry and forest protection respectively, each having its own chief ; and in Ontario a divisional form of organization is used in which the deputy minister is, in effect, in direct charge of forestry work. In British Columbia the Department of Lands and Forests has two deputy ministers, one of whom functions as chief forester. Names of departments

responsible for forest administration, and titles of chief forest officers, are as follows :

province	department	chief forest officer
Nova Scotia	Lands and Forests	Chief Forester
New Brunswick	Lands and Mines	Chief Forester
Quebec	Lands and Forests	Chief of Forest Service Chief of Forest Protection Service
Ontario	Lands and Forests	Deputy Minister
Manitoba	Mines and Natural Resources	Provincial Forester
Saskatchewan	Natural Resources	Director of Forests
Alberta	Lands and Mines	Director of Forestry
British Columbia	Lands and Forests	Deputy Minister of Forests

Authority to administer forests is provided to the department concerned by Acts of the provincial legislature which become provincial laws and contain penalties which may be imposed on any persons who fail to comply with their provisions. Many of these statutes specify the general principles which shall govern the administration, and authorize the Lieutenant-Governor in Council to issue detailed regulations which, when published, have the effect of laws. Such regulations may be amended from time to time by Order-in-Council, and in this way adjustments needed to meet changing conditions can easily be made without referring each minor point to the legislature.

Organization of forestry research

The Dominion Forest Service is the principal organization in Canada in the field of forest research. It is constituted as a bureau of the Lands, Parks and Forests Branch of the Federal Department of Mines and Resources, and is headed by the Dominion Forester. In addition to its investigative functions, the Forest Service acts as a co-ordinating agency in matters of common concern to forest authorities throughout Canada, prepares composite reports on the forestry situation in the Dominion as a whole, and acts as adviser on forestry questions to other departments of the Dominion Government. The Forest Service also represents Canada at Empire and international forestry conferences.

The Forest Service organization includes separate divisions devoted to the study of forest economics, silvicultural research, forest fire protection research, the development of aerial survey methods, and the forest products laboratories of Canada. Regional offices are maintained at Fredericton, New Brunswick, Quebec City, Winnipeg, Manitoba, and Calgary, Alberta, and there are five Dominion forest experiment stations with a combined area of 227 square miles.

Investigations relating to injurious forest insects and tree diseases are conducted by the entomological and pathological divisions of the federal Department of Agriculture. Specially trained officers in that Department are assigned to forestry problems and work in closest co-operation with the

Forest Service. In general, the activities of the Dominion in these fields are restricted to investigation and the development of control methods, while actual control operations are the responsibility of the provincial authorities.

A few special investigations in connexion with forestry are conducted under the direction of the Associate Committee on Forestry of the National Research Council. These are principally concerned with such matters as genetics and hybridization.

Of the eight provinces maintaining forest services, four carry out forest research work to a greater or lesser extent. The four universities which maintain forest schools undertake limited research activities but these are for the most part executed in co-operation with the provincial governments and may be considered as integral parts of the research programmes of the provinces concerned.

A limited amount of forest research work has been carried on by a few of the larger pulp and paper companies and by at least one large lumber company. The Woodlands Section of the Pulp and Paper Association of Canada has recently added special research officers to its regular staff.

Interchange of results of experimental work conducted by forest authorities in Canada is effected mainly through the Dominion Forest Service and through the Canadian Society of Forest Engineers, the national organization of professional foresters. It may be admitted that there is a good deal of room for improvement in the distribution of research plans and results.

Co-operation with Commonwealth Countries

Canada has participated in the series of Empire Forestry Conferences which were held periodically in the interval between the two great wars. At the present time reports are being prepared for presentation at a further conference which, it is understood, is to be held in the United Kingdom in the summer of 1947.

The contributions of Canada to the support of the Imperial Forestry Bureau are made through the National Research Council. It may be noted that a Canadian forester served as deputy director of that Bureau for a number of years.

Periodic reports of the work of the forest products laboratories in the United Kingdom, India, Australia and Canada are regularly interchanged. These include information on new developments in the field of wood chemistry.

It has been indicated that the forestry problems in Canada differ widely from those which are common to many other parts of the Commonwealth. Nevertheless, it is believed that much information of great potential value to Canadian foresters is available in the United Kingdom, our sister Dominions, India and the Colonies. At the same time, there may be much in Canada of value to those working elsewhere. Very useful opportunities for the interchange of scientific and other information are afforded by the Empire Forestry Conferences but it is believed that this interchange could advantageously be supplemented by the organization of extended tours throughout the forests of the Commonwealth by selected forest officers.

RESEARCH ACTIVITIES

(Geodetic Service of Canada, Surveys and Engineering Branch Department of Mines and Resources)

RESEARCH UNDERTAKEN DURING LAST TEN YEARS

Refraction

During 1940 an investigation of the coefficient of refraction prevailing in the Victoria, British Columbia, area was undertaken at the request of the Department of National Defence. The variable results obtained for ranges by depression range finders indicated that refraction was not only higher than the usually accepted average, but also that extreme values were likely to be met with at various times of the day.

The basis of the determination of the refraction coefficient geodetically is a triangulation from which the lengths of the lines are known. Zenith distance readings were taken as nearly as possible in the reciprocal sense over the various lines, but no use was made of this factor other than in the determination of the differences of elevation trigonometrically. The zeros of the staff gauges giving the state of tide were connected to the level system.

Over the triangulation lines electric signal lights were used as targets, thus providing a very fine mark for zenith distance pointings with a one-second instrument. In order to obtain a suitable measure of the refraction at two-hour intervals, during daylight hours the programme consisted of three pointings of the telescope direct, followed by three pointings with telescope reverse, with appropriate zenith distance readings over lines with signal lights ; and two direct and two reverse pointings over lines to lighthouses and to the sea horizon. The mean value of the pointings on each line was treated as an observation.

Air temperature readings were taken at each station and the aneroid read for barometric pressure. This was followed by readings of the staff gauge, air temperature at 1 metre above the sea, and the temperature of the surface sea water. It was recognized that the temperature gradient so obtained would be only a rough approximation due in some degree to the lag between station and sea level observations, but it would serve to indicate very closely variations in process in the vicinity of each station, from which general conditions of the atmosphere over the line under consideration could be inferred.

The temperature gradients obtained definitely indicated that the refractions at the two ends of a line were unlikely to be equal, so all coefficients were determined upon the basis of the zenith distance readings at each end used separately, together with the difference of height determined trigonometrically, or by combination of water transfer and levelling in the case of lighthouses. An advantage of this method is that no assumption is made that the observations are truly simultaneous, a condition which is seldom realized in practice.

A comparison of the observed coefficient with that determined from the pressure and temperature data, as obtained from Helmert's formula, was made, and indicated markedly divergent values, with some cases showing negative computed values when positive instrumental values were observed. There can be but one explanation and that is the temperature readings at the station and at sea level do not represent the conditions as they exist over the lines observed.

An example of variable refraction is summarized below for 17 June :

hour	zenith distance	coefficient of refraction	
7.06	90° 12′ 33·6″	0·215	
7.20	13·4″	0·247	
9.10	31·5″	0·218	
11.03	90° 13′ 45·3″	0·105	
13.06	90° 12′ 58·4″	0·176	
15.06	58·0″	0·178	
16.01	90° 10′ 02·0″	0·450	mirage con-
16.05	28·0″	0·411	ditions with
16.11	18·0″	0·426	maximum
16.21	00·0″	0·453	gradient
16.40	90° 11′ 18·0″	0·333	
19.04	90° 13′ 06·8″	0·164	

and in comparison, for 20 June, over the same line :

hour	zenith distance	coefficient of refraction
7.04	90° 14′ 04·0″	0·075
8.52	01·4″	0·079
11.06	90° 13′ 58·1″	0·084
13.01	58·5″	0·083
15.08	90° 14′ 01·7″	0·078
17.06	90° 13′ 49·4″	0·099
19.06	90° 14′ 02·8″	0·077

in which regular and small values for the coefficient of refraction were observed.

A few of the conclusions arrived at as a result of 398 coefficients obtained on the sea horizon and 1390 coefficients obtained on lines of varying height over the sea, the observations extending over the period 16 May to 6 July, are as follows :

The area is one in which inverted temperatures exist during the day in summer as a general condition.

A return to normal cooling with height occurs only when winds are strong, say, over 25 miles per hour.

Winds of less strength than 15 miles per hour are not sufficient to keep the air thoroughly mixed and lenses of various densities occur over the area.

During the period of the observations, the wind direction was from the south-west and west with very few exceptions.

For winds of less than 15 miles per hour, no approach to the accepted mean value of the coefficient of refraction of 0·07 is possible. For higher winds, sea horizon values of the coefficient of refraction are well represented by 0·115 and other lines by 0·084.

The grand mean of the coefficient of refraction for the sea horizon is 0·127 and for other lines 0·112.

Variations in refraction are encountered to a lesser extent the higher the station, and from 250 ft elevation to higher elevations, the refraction is quite stable.

The normal daily curve, in which the means by hours approach a minimum at the time of maximum temperature, has only been obtained for the higher lines. All the curves obtained indicate the mixed conditions prevailing over the area in the lower strata, and indicate inverted temperature conditions.

International spheroid

On the North American continent, the spheroid of reference upon which geodetic computations have been based is the Clarke spheroid of 1866. In parts of Europe, the Bessel ellipsoid of 1841 is in common use. In 1924, after years of study in a number of countries, a spheroid of reference designated as the international spheroid, whose dimensions are almost identical with the Hayford spheroid of 1909, was adopted at the Madrid convention of the International Union of Geodesy and Geophysics for use wherever possible.

Since the international spheroid has been adopted internationally for use where possible with dimensions closer to the actual dimensions of the earth than any other spheroid of reference, it is possible that it will be ultimately used as the basis of geodetic computations in North America. The problem will then arise of devising the most economic methods of computations for the transference of thousands of geodetic triangulation stations in each country from the Clarke spheroid of 1866 to the international spheroid.

Research work has been carried on in the past by the Geodetic Service of Canada and a differential formula has been developed for the transference of latitudes from one spheroid to the other with considerable saving of time and labour. The development of analogous differential formulae for changing longitude and azimuth proved on investigation to be so complicated as to give no marked advantages over previous longer methods.

Geodetic formula for long lines

Where geodetic positions are to be computed or inverse solutions made of lines exceeding 100 miles in length, special methods must be developed to ensure accuracy of results. Formulae used for lines usually met with in triangulation are not applicable in general to lines over 100 miles long. Research has been carried on in this field using two methods of approach. Some of the results have already been published but the more recent work is still in manuscript form.

Maps for transpolar air navigation

During the war, investigational work has been carried on in connexion with transpolar navigation. As the existing methods of astronomic position fixation from the air were not in general applicable to polar latitudes, it was necessary to modify existing methods or develop certain new features. The Mercator map projection in general use for lower latitudes was unsuitable for areas near the pole. The astrograph system of projecting shadows of position lines on to the chart was also unsuitable during the summer months, when the continuous daylight in polar regions prevented the shadows being seen.

As an alternative, star altitude position finding curves were worked out for latitudes between 65° and the pole. These curves were designed for use with thin transparent charts placed directly in contact with the star altitude curves, so that the position lines might be seen when the map was superimposed over the curves. For observations on the sun, moon or planets, a system of slotted templates was developed whereby position lines could be lain down with a minimum of computation during flight.

Isostasy

Up to 1939 the Geodetic Service of Canada has observed ' deflections of the vertical,' both in the meridian and prime vertical, at approximately three hundred triangulation stations in Ontario, Quebec and the Maritime Provinces. Corrections for topographic and isostatic compensation were applied to these deflections. A solution to determine the height of the geoid was made, and the elevations of these geoidal curves were carried from Calais, Maine, on the Bay of Fundy to Warwick, Ontario, on Lake Huron, by way of the Atlantic coast, St Lawrence Valley and Ontario. It was found that the geoidal curves on Lake Huron, Ontario, were approximately 10 metres lower than those at Calais, Maine.

Map control

For the past five years the Geodetic Service has carried on extensive campaigns for the determination of latitude and longitude for control of mapping. The method of observing is somewhat similar to the Ball method of equal altitudes. The instruments used are the $5\frac{1}{2}$-inch Wild transit, and besides the transit the only instruments necessary are a sidereal chronometer, a good stop watch and a wireless receiving set for the reception of wireless time signals. If thought advisable, a chronograph could replace the stop watch, but in order to reduce the weight of the outfit, four of the five parties employed used the stop watch. The results obtained by either the watch or chronograph are of equal precision. A determination of time and latitude is obtained from four stars, one in each quadrant, N.E., S.E., S.W. and N.W. The best results would be obtained by selecting stars in azimuths 35°, 135°, 225° and 315°, but as that is impracticable and often impossible, the stars selected should be at least 20° from the meridian or prime vertical.

Attention is drawn to the fact that this method of geographical determination is capable of a high degree of accuracy. Its precision depends on making the observations of the four stars in the different quadrants at

a fixed altitude. This altitude is generally either 60° or 45° and great care must be taken to ensure this constant by means of the level attached to the altitude circle of the transit.

At several stations observed during the last five years, observations were obtained on two or more nights, and it is safe to conclude that the probable error obtained is less than ·50 second of arc. On 22 and 24 March of 1946, two nights' observations were made at Cambridge Bay, N.W.T., by an engineer of the Geodetic Service of Canada attached to the 'musk ox' exercise, and the results of the observations were as follows :

	22 March 1946	24 March 1946
longitude . .	7 hr. 00 min. 02·91 sec.	7 hr. 00 min. 02·93 sec.
latitude . .	69° 07′ 16·02″	69° 07′ 15·25″

The temperature at which these observations were made was 25° below zero, Fahrenheit.

RESEARCH NOW UNDER WAY

Isostasy

During the present year it is planned to continue the determinations of longitude and latitude and to develop further this investigation on the figure and size of the earth.

Radio communication in geodetic field work

Radio communication has two different functions for field survey use. First, that of the reception of standard time signals, and secondly, the interchange of messages between scattered parties and their base stations.

With respect to time signal reception, the transmission of continuous signals, such as those originating at the Dominion Observatory, Ottawa, and transmitted by the Radio Service of the Department of Transport between dusk and dawn for the period during which observations are taken, proved more useful than those signals sent out for five minute periods at the end of specific hours. These continuous signals enable the field engineers to record the standard time at periods of favourable reception, which may not coincide with the signals transmitted at the end of the hour. A similar service in maintained during both day and night by the Bureau of Standards, Washington, D.C., over radio station WWV.

In northern latitudes these continuous signals offset in some measure the effect of the Aurora, which at times creates a complete 'black out' for wireless reception.

Intercommunication between scattered field parties and their base is essential when aircraft are used for transport. A small and light transmitter-receiver unit operating on both R/T and C/W has proved extremely useful. These units, originally designed for forestry use, have an output of 2·5 watts and under average conditions for reception have a range of 100 to 200 miles. They have given particularly good service in the treeless area of Northern Canada. Communication in the western and eastern

sections has proved erratic, probably due to the rugged topography. Many blank spots for local reception were found in the mountainous regions of British Columbia and the Yukon, while similar conditions are found in the areas north of the lower St Lawrence River system.

Polar map projections

Since the close of the war, additional investigational work has been carried on in connexion with map projections suitable for air navigation in polar areas. A modification of the Lambert conformal projection with two standard parallels was worked out and compared with a stereographic polar projection. The theoretical scale errors were deduced for each projection showing that the modified Lambert gave a better distribution of errors over the whole chart.

For laying down great circle courses on either of these polar projections, a nomogram was developed making unnecessary the use of an auxiliary gnomonic projection for plotting the position of long courses. With the nomogram, the great circle course joining any two points may be quickly and accurately drawn without any computation whatsoever.

For use in testing the accuracy of the nomogram and studying the errors of scaled distances and azimuths of various projections, seven great circle courses crossing polar or sub-polar latitudes are being worked out. Intermediate points at intervals of two or three hundred miles on each great circle course are being determined. The true azimuths at each point and the intervening distances are also being deduced by geodetic formulae, so that accurate comparisons can be made with the corresponding scaled values.

Approximate latitude determination using Vega

In Northern Canada extensive use is made of second order astronomical fixes (within about 300 feet) for latitude and longitude as control for aerial mapping. An approximate value of the latitude is required as a preliminary to the actual positional observation, and this may be conveniently determined by observation on the sun or Polaris. However, in latitudes north of 63° it is sometimes not possible to elevate the theodolite telescope sufficiently to get Polaris in the field of the telescope. In such cases, some other star must be used and Vega (α Lyrae) has proved to be satisfactory.

This star is readily seen in the telescope during the daytime (being of first magnitude) and its position in the sky throughout the summer months makes it very suitable for afternoon and early evening observation.

To locate the star during daylight, curves for the altitude and the azimuth are employed. These curves are computed from the formulae.

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos (\theta - \alpha)$$

and

$$\sin A = \cos \delta \sec h \sin (\theta - \alpha),$$

where

h = observed altitude,
ϕ = approximate latitude,
δ = declination of Vega,
α = right ascension of Vega,
θ = sidereal time,
A = azimuth.

In practice, altitude and azimuth curves are drawn for each degree of latitude. When the star has been found, an observation of altitude and azimuth is made at a chosen time and the latitude calculated by means of the formula

$$\tan \tfrac{1}{2}\phi = \frac{\sin \frac{1}{2}(t-A)}{\sin \frac{1}{2}(t+A)} \cot \tfrac{1}{2}(\delta - h)$$

where the symbols have the same significance as above and

$$t = \text{the hour angle} = (\theta - \alpha).$$

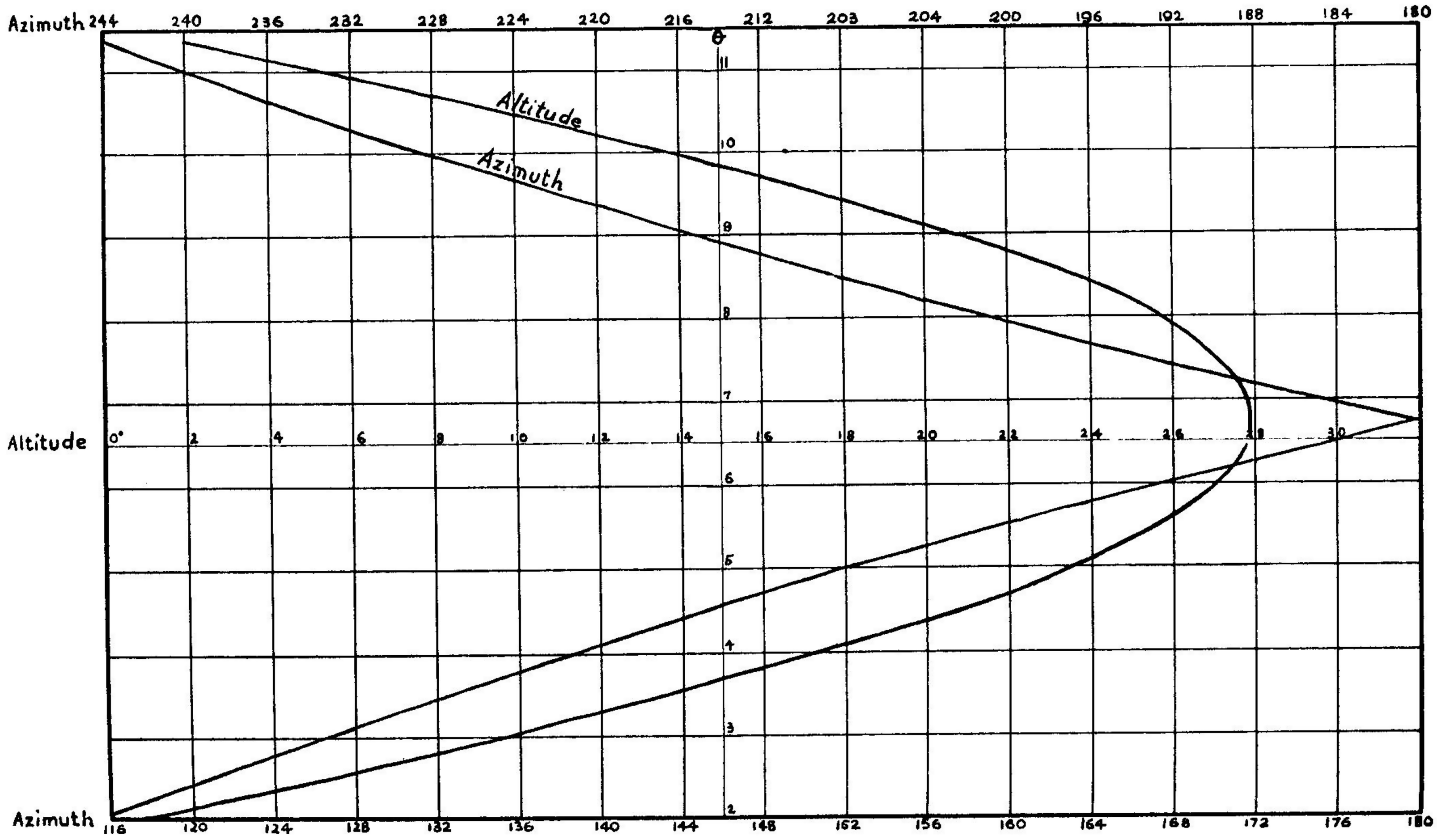
In the diagram on p. 90 the time scale θ is the argument for both altitude and azimuth. The lower azimuth scale refers to the lower branch of the azimuth curve and the upper scale refers to the upper branch. The middle horizontal scale refers to the altitude curve.

RESEARCH CONTEMPLATED FOR THE FUTURE

Triangulation adjustments

In connexion with the least square adjustment of triangulation nets, it is proposed to make a study of the factors and conditions causing instability in solutions. In simple nets of triangulation, this problem seldom presents itself but in large and complicated networks, delays and recomputations sometimes result from incomplete knowledge of the cause of instability. By introducing angle, side and length equations into a small experimental net, in a number of different ways, it is hoped to find the effect of changing the position of the poles of a side equation, of changes in the route of Laplace equations, and the effect of a change on selecting a side equation where a number of choices may be made.

Note : These sample curves are for the star Sirius and latitude 45° 23′ N.



DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B.C.

Department of Mines and Resources, Surveys and Engineering Branch

RESEARCH WORK 1935–1945

During the war years research was naturally seriously interrupted. Three astronomers were on loan to other organizations for varying periods, and a considerable proportion of the time of others was taken up with work directly or indirectly connected with war activities. However, it was found possible to keep the telescope working at nearly normal efficiency, and about 14,000 spectra were obtained during the ten-year period. The activities may best be described under six main heads as outlined below.

1. Stellar radial velocities

(*a*) *Radial velocities of the faint O- and B-type stars.* An extensive programme of 1,000 stars of classes O and B between magnitudes 7·50 to 10·00, north of the celestial equator, was pursued. This programme was an extension of the former research of Plaskett and Pearce on the bright O- and B-class stars. Since the number of the stars is large and their magnitudes faint, requiring long exposures, even with the fastest spectrographic plates available, the Lick Observatory was requested to co-operate by observing all stars between the equator and declination 20 degrees south. Satisfactory progress has been made in the observing of these stars, but the measurement of plates is far behind. At the present rate about eight years will be required to complete this research.

(*b*) *Wave-length tables.* The radial velocity work included the investigation and revision of the wave-length tables to place the velocities on a fundamental and homogeneous system. The tables for the late type stars, F_4—K_8, for both single and double prism spectrographs, have been completed, and work on similar tables for stellar types O, B and A remains to be done.

(*c*) *Measuring machines.* The instrumental field was not neglected. The past decade saw the successful development of projection methods for the measurement of stellar radial velocities, and recent studies promise the development of labour-saving instrumental advances in radial velocity work.

2. Investigations of binary stars

A large amount of time was devoted to studies of spectrographic binary systems along the following lines :

(*a*) *Rotation of the line of apsides.* Some twenty binaries were followed with high dispersion in order to study the problem of orbital variations. A rotation of the line of apsides was detected in six systems and the density of distribution of mass in the component stars deduced.

(*b*) *Spectroscopic binaries.* The orbital elements of some twenty-five systems were computed. The principal reason for continuing work in this field is to provide accurate data for the revision of Eddington's mass-luminosity relation.

(*c*) Δm *determinations.* A new type of investigation was opened with the development of spectrophotometric methods of studying the magnitude difference in double star systems. This has led to a knowledge of the individual masses and luminosities of the components, from which the absolute magnitudes may be deduced.

3. Spectrophotometric observations of the emission line stars

The science of spectrophotometry has developed largely during the past decade, and considerable contributions were made in this field. A powerful self-registering microphotometer was designed and constructed for the analysis of stellar spectra, and a calibrating spectrograph assembled for calibrating all plates taken for the purpose of spectral line studies. By means of the microphotometer the spectral features are magnified 100-fold, so that the contours of the spectral lines may be drawn and integrated by a planimeter in order to determine the total intensities of the lines. To speed up the laborious spectrophotometric reductions, a new instrument which was named an intensitometer was devised. This not only permits a further enlargement of the spectra to a 400-fold size, but enables the intensities to be computed in one-seventh of the normal time.

(*a*) *Wolf Rayet stars.* The ultimate purpose of this study, as of most strictly astrophysical studies, is to ascertain the behaviour of matter when assembled in stellar masses of the order of 100,000 to 10,000,000 times that of the earth. Astrophysical discoveries of the first three decades of this century showed conclusively that such aggregations of matter, under the influence of gravitational and other forces, become self-luminous with the observed surface temperatures of the stars, and with internal temperatures of millions of degrees. These deductions, as is well known, were derived initially from studies of the surfaces of absorption line stars, like the sun, beginning with the chemical composition as revealed by the spectral lines, and proceeding to the temperature of the radiating surface, the density and pressure of the atmosphere, its general level of ionization, and the physical processes by which radiation is transferred through it. At the time this work was undertaken, such data were reasonably complete for absorption line stars, but the corresponding material was lacking for the emission line objects. A beginning was made with the well known groups of Wolf Rayet stars, having wide emission bands. It was shown that the emission bands had their origin in an outer shell of atoms, which were continually being ejected into space. The maximum velocities of ejection were of the order of 3,000 km./sec., and evidence was deduced suggesting that the radius of the shell was large relative to that of the star. It was also shown that the shell of ejected atoms was stratified according to ionization potential, with atoms of lowest ionization potential on the outside. Since the structure of the atmosphere suggested a miniature planetary nebula, Zanstra's well known theory of nebular luminosity was used to derive temperatures, which were found to range from 50,000 to 100,000 degrees, thus making the Wolf Rayet stars the hottest objects

known. The stars were classified according to ionization potential, and were found to be distributed in two parallel sequences, one of which was featured by a large abundance of carbon to the exclusion of nitrogen, while the other had strong nitrogen lines to the exclusion of carbon. Hydrogen and singly and doubly ionized helium are common to both sequences. The Victoria classification of the W stars was adopted by the I.A.U. in 1938.

(*b*) *The P-Cygni stars.* The association of a shell of large diameter with Wolf Rayet emission line objects had immediate application to other stars, and it was recognized almost immediately that this was the fundamental structure of an emitting atmosphere. The same general analysis as that outlined above was applied to the P-Cygni stars and the related objects of α-Cygni type. In this case also, a shell of ejected atoms provides a satisfactory interpretation of the general phenomena of emission. In the case of the P-Cygni stars, absorption plays an important part in the spectrum, and efforts were made to explain the numerous complicated line profiles in terms of the general structure of the atmosphere. It was shown that practically all of the lines could be explained in terms of a blend of the following three components : (i) an absorption line arising close to the stellar surface, at a level corresponding to the reversing layer of the absorption line star ; (ii) an emission line arising in an outer shell several times the stellar diameter ; (iii) an absorption line displaced to the violet, produced by a shell of larger diameter than that producing the emission. The classification of the P-Cygni stars shows that they range from O to A type. Their temperatures were shown to vary from 10,000 to 40,000 degrees, while their diameters vary from 0·16 times the sun for the companion of R Aquarii to 135 times the sun for the star α Cygni. Broadly speaking, it appears that the Wolf Rayet and the P-Cygni stars are objects of high temperature with an excessive output of radiation. The outward stream of radiation is carrying with it a part of the star's mass in the form of ejected atoms, presumably indicating a brief duration for that phase of the star's life.

4. Interstellar matter

The study of interstellar matter has proceeded along two main lines : first, the study of line spectra, due to gases in interstellar space, and secondly, the determination of the relation of the colours of the stars to their distance, an effect which is considered to be due to absorption of light by solid particles. One aspect of the study of line spectra is the relationship between line intensity and distance, a relationship which is of great importance for estimation of stellar distance. Such a relationship has been established and embodied in the form of a curve, relating distances to line intensities for stars as remote as 2,500 parsecs. It is hoped with the aid of the spectra of faint stars to extend this relationship to a distance of at least 4,000 parsecs. Another important aspect of the study of interstellar lines is the relative intensities of interstellar calcium and sodium. It was first definitely shown at Victoria that the sodium lines were in general stronger than those of calcium, in contradiction to all theoretical authorities. All subsequent studies have confirmed this fact. A study of the profiles of interstellar lines, as well as the relation between

distance, intensity and galactic longitude, has shown that their widths are largely a consequence of turbulent motions in the interstellar gas. The study of solid particles has been followed a shorter time than that of interstellar gas, but some of the results may be outlined as follows : there exists a definite relation between distance and the reddening of stars, but it is less definite than might be hoped, indicating a very irregular distribution of the absorbing material. A number of broad absorption features have been tentatively identified as due to absorption by solid particles. They have not so far been assigned to any specific substance, and an effort is being made to stimulate laboratory investigation, looking towards the solution of the problem.

5. The atmospheres of the solar type stars

An intensive study has been made of the atmospheres of the solar type stars. Using the highest dispersion available, spectra have been taken of the sun, α Cygni, α Persei and α Canis Minoris. The intensities of 1,000 lines in the region $\lambda\lambda$ 3,700–6,750 have been measured. A definitive curve-of-growth for the centre of the sun's disc was obtained from measures of lines in the Utrecht Solar Atlas and King and King's f-values for the atoms of neutral iron and neutral titanium. Stellar curves-of-growth were obtained by plotting stellar intensities against solar X_f-values, and from these data information was deduced on the excitation temperatures, the electron pressures, and the composition of the atmospheres, for those elements with measurable lines in this spectral region.

6. Molecular and cometary spectra

The main research projects pursued during the past ten years involved the study of molecular bands in celestial sources, supplemented by a few laboratory studies in the same field. Among the researches completed, mention may be made of the following :

(*a*) A study from laboratory spectra of the isotope effect in the red bands Li_2, leading to a determination of the mass ratio of the lithium isotopes. This is probably the most detailed study yet made of lithium.

(*b*) An examination of data on lines arising from the lowest state of common molecules. The results of this, combined with observations by Dr W. S. Adams of Mount Wilson Observatory, led to the discovery of the existence of molecules in interstellar space.

(*c*) Observations with the highest practical spectral purity of molecular emission bands in several bright comets have been made. The results of this research were (i) the shedding of light on the method of resonance—fluorescence by which sunlight excites the cometary molecules to emit radiation, and (ii) the identification of NH_2 in the heads of comets.

(*d*) An extended study of the molecular bands in the spectra of some thirty-five cool carbon stars of spectral types R and N is being carried out. This has involved a long observational programme extending over the past ten years. The principal immediate objective is the determination of the relative intensities of the bands due to the two carbon isotopes C^{12} and C^{13} to obtain values of the abundance ratio of the carbon isotopes in the stellar atmospheres. Evidence already obtained indicated that the ratio of C^{13} to C^{12} is greater in most cases than for terrestrial carbon, and

that it varies from star to star. The eventual cosmological significance of the results of this work may be considerable in their relationship to the nuclear processes occurring in stellar interiors and to the important related problems of stellar evolution.

PRESENT AND CONTEMPLATED FUTURE RESEARCH

The research problems in progress in all probability will require six to eight years for their completion and the publication of their results. A brief capitulation of these is as follows :

(*a*) The radial velocities of the faint class B stars.
(*b*) Classification of the O- and B-type stars upon new criteria determined spectrophotometrically.
(*c*) Publication of a general catalogue of all known radial velocities as of 1 January 1950.
(*d*) Classification of the omission line stars of the Wolf Rayet, P-Cygni and α-Cygni types.
(*e*) Completion of the research on interstellar matter, extending the observations to more distant objects, in order to have available for analysis a more representative sample of interstellar space.
(*f*) Continuation of the research on emission line stars in order to elucidate the nature of the forces responsible for the peculiar surface phenomena ; and secondly, if possible, to make a contribution to the problem of their inner structure and the mechanism responsible for the excessive output of stellar energy.
(*g*) Determination of the masses and dimensions of massive binary systems discovered during the course of the radial velocity programme.
(*h*) The study of apsidal motion in close massive binary systems.
(*i*) Completion of the research on the unidentified blue-green bands in the spectra of the carbon stars ; the determination of their excitation temperatures from the intensities of the various bands ; and the detailed comparison of the spectra of the peculiar CH stars with those of normal R type.
(*j*) Preparation of complete intensity profiles of extended spectral regions of the spectra of the R and N stars.
(*k*) Studies of the atmospheres of representative giant and dwarf stars of spectral classes F_0—K_5, extending our knowledge of curve-of-growth phenomena.

DOMINION OBSERVATORY, OTTAWA

Department of Mines and Resources, Surveys and Engineering Branch

RESEARCH WORK, 1935–1945

Meridian work

(*a*) *Star positions.* Telescopic equipment consists of a six-inch reversible meridian circle, originally built by Troughton and Simms, but with many improvements and alterations carried out in the observatory machine shop. It is equipped with a hand driven travelling wire micrometer, a zenith-distance micrometer with type wheel for recording star pointings and two three-foot circles. Eye-end and object-end are interchangeable. Registration of transits is accomplished by a drum chronograph or a printing chronograph. North and south azimuth marks of the underground type are provided, with provision for referring the lenses and marks actually sighted on to the optical centres of underground lenses placed over mercury surfaces. There is a personal equation machine mounted on the pier of the south azimuth mark. Screens are provided to reduce the apparent magnitudes of the brighter stars to a common standard. A thorough determination has been made of pivot errors and of division errors of both circles.

The instrument is housed in a stone annex connected to the main observatory building, with flat concrete roof and comparatively narrow observing openings. In earlier years, notwithstanding these defects, the possibility of successful fundamental observations was thoroughly tested. It was found that, especially near the junction points of roof with north and south walls, refraction effects came into play which entirely vitiated attempts to determine fundamental declinations. Similarly, refraction effects in the prime vertical induced by the concrete roof and the proximity of the higher main building effectually prevented satisfactory determinations of fundamental right ascensions.

However, the equipment is good, and is well suited to the differential determination of star positions, and in recent years observations have been confined to this objective. During the war years retirements and illness among the staff greatly reduced the observational output. Computation of earlier observations has, however, made reasonably good progress.

(*b*) *Time service.* Time observations are made, usually every clear night, with a three-inch astronomical transit of the broken tube type, with hand driven travelling wire micrometer ; collimation is eliminated by reversal of the instrument in the middle of each star observation. Primary clocks consist of one Shortt ' free pendulum,' three Rieflers and one crystal clock. The four sidereal pendulum clocks are mounted in separate rooms in an underground clock vault, each room having a separate temperature control. Another crystal controlled clock operated by 1000 cycle current from a monitoring station of the Department of Transport is also available. Comparisons among these six primary clocks are made twice daily by

means of the micro dial of one of the crystal clocks or by a high speed chronograph reading to ·001 second. In combination with the star observations, a smoothed correction curve is thus obtained for the clock used as standard, usually the Shortt.

For control of the various mean time circuits required for internal use and for general time distribution, a special time signal clock was designed and constructed. This consists of a self winding weight driven clock mechanism with escapement operated by a half seconds pendulum, and with parallel shafts rotating respectively in a day, an hour, five minutes and one minute. By suitable arrangement of contact wheels mounted on these shafts any desired programme of time signals can be provided. At present about ten different primary circuits are in use, and these are sub-divided for distribution as required. Provision is made for synchronization of the time signal clock by the sidereal clock used as standard. As an integral part of the mechanism, an automatic comparison is made at each coincidence interval (6 minutes, 5 seconds, approximately), and the required correction applied to the half seconds pendulum. To provide for this, a micrometer head in the signal clock mechanism indicates at all times the adopted correction of the sidereal clock, this indicated correction being continually changed by insertion of the adopted rate.

During the last several years the distribution of time signals has been substantially as follows :

(i) Daily broadcast over the C.B.C. network for about 30 seconds at 1 p.m., Eastern Time.
(ii) Daily broadcast over Department of Transport station VAA, 11.55 to 12.00 noon, Eastern Time.
(iii) Two daily broadcasts over Naval station CFH, Halifax, 9.55 to 10.00 a.m. and p.m., Eastern Standard Time.
(iv) Daily broadcast over Department of Transport station VAP, Churchill, 10.58 to 11.00 a.m., Eastern Standard Time.
(v) Continuous broadcast over low power Observatory station CHU.
(vi) Daily distribution over Canadian National telegraph lines, 10.58 to 11.00 a.m., Eastern Standard Time.
(vii) Daily distribution over Canadian Pacific telegraph lines, 11.54 to 11.56 a.m., Eastern Standard Time.
(viii) Continuous transmission over private line to Department of Transport monitoring station, Ottawa.
(ix) Continuous transmission over private line to National Research Council, Ottawa.
(x) Continuous transmission over private line to C.B.C. station CBO, Ottawa, for general use of C.B.C. service lines.

Solar physics

In many cases the investigations outlined below were not confined to the ten year period mentioned above, but were a continuation of studies initiated earlier, with a view to confirmation or extension of previous work. Observing, measuring and computing have been greatly facilitated by specially designed apparatus and computation tables.

(*a*) *Spectroscopic work.* The observing routine consisted of photography (with 20-inch coelostat and 19-foot horizontal grating spectograph) of selected points on the solar disc, sunspots and comparisons, involving simultaneous observations of nine strips of spectra of centre, midway and limb points, with iodine absorption and electric arcs, for measurements of solar rotation, solar distance, wave-lengths on the solar disc and velocities in sunspots. Some of the results follow. Errors due to blended spectra were found to vary with the intensity of the spectrum lines and could therefore be estimated and so eliminated. Rotation velocities in some of the earlier years, after elimination of these errors, revealed no difference due to elevation up to 2,500 km. in the solar atmosphere, and this appears to be confirmed by later results. Rotation velocities appear to be represented by a simple law of the solar rotation, thus (ϕ being latitude and n being ·315), $V = 2{\cdot}02 \cos^{n+1}\phi$ km. per sec., or $A = 14^\circ \cdot 37 \cos^n\phi$ per day. From the above law, the rate of change with latitude of the kinetic energy of rotation of the solar surface attains a maximum for $2n+1 = \cot^2\phi$, or for $\phi = 38^\circ$, near which latitude initial sunspots in a new cycle appear. The rate of the equatorward drift of sunspots was found to be proportional to the rate of change of linear rotation with latitude, or to $\cos^n\phi$, where $n = {\cdot}315$. Investigation of the law of the solar rotation led to the discovery that the intensity of radiation from the solar disc, at angle ρ from the centre, was proportional to $\cos^n\rho$, where n is about $\cdot 30/\lambda$ for light of wave-length λ, and ·33 for total light. Sunspots spectra were measured in relation to the solar rotation work, and to the Ottawa pore theory of solar wave-length variations and limb effect, which assumes that the pores have a convective system similar to that in spots (Evershed effect).

(*b*) *Sunspot influences.* A study has been made of co-variants in the solar system, especially the terrestrial variations accompanying the 11-year sunspot cycle. It appears to be proper to ascribe to the hot high level faculae, flocculi and prominences a relatively large emission of ultra-violet light, which ionizes the upper atmosphere of the Earth, inducing electromagnetic disturbances and meteorological variations affecting in turn all forms of life. Various Canadian correlations have been found. (i) Physical effects : precipitation, thunderstorms, lake levels, Niagara River flow, temperature, dates of freezing in Montreal and Quebec harbours. Positive and negative phases were found for precipitation in different areas, the phases being opposite for coastal and mid-continental regions, with negative phase for temperatures, thunderstorms and dates of freezing. (ii) Organic effects : the sunspot influence has been found in many records investigated—animal and bird life, insects, diseases, vegetation, especially tree growth, which in general follows the phase of the precipitation cycle across Canada. An interesting case was that of pre-glacier tree growth, the cycle being found in two specimens released from the retreating glacier in northern British Columbia. (iii) The 4-year cycle in lemmings, snowy owls and arctic foxes has been ascribed to the similar cycle found by the Lockyers in solar prominences and barometric pressure. (iv) A combination of the sunspot cycle and the 8·85 year and 18·6 year lunar cycles accounts for many terrestrial variations, especially the 10-year cycle in the fur bearing animal records. (v) Considerable work was done on the possible influence of the planets in inducing the

sunspot cycle. Co-variants of the 260-year period in errors of the moon's longitude have been found. The break in meteorological conditions just before the middle of the last century has been ascribed to a sudden variation in arctic ocean currents.

Terrestrial magnetism

(*a*) *Magnetic observatories.* Two magnetic observatories have been in continuous operation, one at Agincourt, Ontario, since 1898, and the other at Meanook, Alberta, since 1916. These were taken over from the Meteorological Service in 1936. Meanook is situated on the southern fringe and Agincourt to the south of the maximum auroral frequency zone. Continuous photographic registration of the magnetic elements, declination, horizontal and vertical force, is maintained at both observatories. During the past ten years, as before, daily, monthly and annual mean values of the elements have been measured and all data dependent on these measurements derived. K indices for three-hour intervals have been measured as a regular routine.

(*b*) *Field work.* Field work has consisted mainly of the reoccupation of repeat stations for secular change, and the extension of the network of base stations to the Arctic regions of Canada. In the Eastern Arctic the survey has reached the southern coast of Ellesmere Island. The elements measured at field stations are declination, horizontal force and inclination. At northern stations total force is substituted for horizontal force. Considerable progress has been made in the studies of daily variation and disturbances peculiar to the areas in and adjacent to the auroral zone. During the war years the field programme was adjusted to serve the needs of the armed forces. Isomagnetic charts of the North Polar region were constructed for use in air navigation, and magnetic observations were made at naval bases. Considerable co-operation was also afforded in setting up and maintaining apparatus for the testing of compasses for the armed services.

Gravity

Since the inception of the gravity survey over 150 pendulum stations have been established throughout Canada. Of these, forty in Eastern Canada and Newfoundland were occupied during the period under review and previous to the war. A number of the occupations were made with the object of determining whether or not, as had been suggested, the Timiskaming earthquake of 1 November 1935 had been accompanied by a measurable change in gravity. Apart from the usual purpose of such observations, others were made with a view to the investigation of possible relations between gravity anomalies and geological structure of the Appalachian and Acadian regions of Eastern Canada. Still other stations were established to serve as base stations for torsion balance surveys and for proposed future work with gravimeters.

All Canadian stations have been reduced by the Free Air, Bouguer, Hayford-Bowie and Airy-Heiskanen methods. Twenty-five in Eastern Canada have also been reduced by the Vening Meinesz method. The Airy-Heiskanen reduction indicates a thickness of crust in Canada varying from 37 to 50 kilometres. The most probable depth of compensation

corresponding to the Hayford method, and deduced from 128 observations in Canada, is 85 kilometres.

During the early years of the war the gravity personnel was on loan for war work, and later was engaged in general geophysical work as indicated below. Pendulum work was resumed in 1945, during which eight stations were occupied in Northern Canada.

Seismology

During the period under review the seismological stations previously established in Canada have been continuously maintained. Their records have been regularly analysed at Ottawa and reports with full data have been issued monthly to all operating seismological stations of the world. These normally numbered about 250, but during the war the number was considerably curtailed.

(*a*) *Instrumental equipment.* At Ottawa the equipment comprises a Benioff vertical seismograph with long and short period registration, together with two Miln-Shaw horizontal instruments, the latter with clock-work and recording drum constructed at the Observatory. At Halifax the previous obsolete smoked sheet Mainka installation was replaced in 1938 by Bosch photographic horizontal instruments, originally in use at Ottawa ; these are operated and serviced at Dalhousie University. The Mainka instruments at the University of Saskatchewan, Saskatoon, were similarly replaced by Milne-Shaws with recorders built at Ottawa ; this installation was completed in 1945. At Victoria a new vault was constructed in 1939 on the grounds of the Dominion Astrophysical Observatory, and the two Milne-Shaw horizontals and the obsolete Wiechert vertical, previously at the Meteorological Observatory, were installed. At Shawinigan Falls and Seven Falls, Quebec, where stations were installed and operated through the co-operation of the Shawinigan Water and Power Company, the equipment remains as originally established in 1927—a single component Wood-Anderson at Shawinigan Falls and a similar instrument plus a single component Milne-Shaw at Seven Falls.

(*b*) *Timiskaming and Cornwall earthquakes.* On 1 November 1935 a severe earthquake occurred near Timiskaming, Quebec. On 5 September 1944 another occurred near Cornwall, Ontario. These two earthquakes were studied in the field and by means of all available seismograph records and questionnaires. Reports were published on the analyses. The final report on the Cornwall earthquake is still to appear.

(*c*) *Bibliography of Seismology.* The *Bibliographical Bulletin* begun in January 1926 under the auspices of the Seismological Society of America, Eastern Section, became the *Bibliography of Seismology* in January 1929. From that time to date it has been published regularly. It is to-day recognized as the international bibliography in the field of seismology. Collaborators in all countries active in the seismological field assist in the compilation. It is issued as one of the publications of the Dominion Observatory. Prior to the war, it appeared quarterly. Since January 1941 it has been published only twice yearly, due largely to the marked reduction in seismological publications as a result of the war. These are now increasing in number, and indications are that the *Bibliography* may soon again become a quarterly.

(*d*) *Rockburst investigations.* On 27 December 1938 a severe rockburst occurred at Lake Shore Mines, Kirkland Lake, Ontario, which was registered at Ottawa at a distance of 278 miles. After discussion of the subject of rockbursts with the management, the mine undertook to finance the establishment of a seismograph station at Kirkland Lake. This was placed in regular operation on 19 December 1939. The mine then asked that the observatory undertake an extensive programme of research with a view to predicting rockbursts. This was begun at once and continued without interruption till 1 November 1945.

Several methods of checking on strain conditions were attempted and found inadequate for various reasons. The method which was investigated most carefully was that based on the assumption that rocks under serious strain would probably produce sub-audible snaps (later named microseismims), the incidence rate of which might be expected to increase as the strain approached bursting conditions. This work began independently in the Lake Shore research and was well under way when it was discovered that a similar programme was being carried out by the U.S. Bureau of Mines under the direction of Dr Leonard Obert. The two programmes were thereafter carried out with close co-operation.

Laboratory experiments at Washington show that the basic assumption is sound. Extensive study at Lake Shore mines confirmed the fact to the satisfaction of those carrying out the work. Unfortunately, the very broken nature of the rock at Lake Shore mines results in the critical pressure points shifting so rapidly (within a few hours) that a given critical point may give a high microseismim count at a given time and actually be under dangerous pressure, but the pressure may redistribute itself before a burst occurs. This fact and the markedly reduced number of bursts due to reduced mining conditions made satisfactory prediction difficult. The programme was discontinued on 1 November 1945, after three and a half years of high pressure study involving expenditures by the mine of some $125,000. They expressed themselves as well satisfied with the information gained. The results from a purely scientific point of view were most valuable.

During the time the research was in progress, eighteen bursts occurred which were recorded at Ottawa. Some of these were also recorded at Shawinigan Falls and at Weston, Massachusetts, at distances of 358 miles and 581 miles respectively. These data form the basis of two published studies on seismic wave propagation in the Canadian Shield. The previous data also make possible that any future burst at Lake Shore mines sufficiently severe to be recorded at Ottawa can be timed to a fraction of a second by means of the Ottawa record. This fact is the basis of a proposed research on the structure of the Canadian Shield.

Applied geophysics

The general policy in this field has been to avoid geophysical surveys conducted for commercial purposes, but to co-operate so far as possible with federal or provincial organizations in experimental work, or in some cases in the location of underground deposits when this has been judged to be in the public interest.

The field of seismic prospecting has been well developed, and is largely

in the hands of private companies. In 1938, and again in 1939, to keep a check on methods employed, the observatory seismologist spent some little time with seismic survey parties in southern Alberta. Similar visits to other areas have been made. But no actual work of this nature has been carried out by the Canadian Government.

Previous to the period under consideration, considerable experimental work was done by gravitational and magnetometric methods. A general description of this work was issued as an observatory publication in 1940. Since 1943, investigations have been made in New Brunswick with torsion balances, magnetometers and a gravimeter, for the purpose of tracing buried geological features possibly associated with the occurrence of oil. Some 500 gravimeter stations were established in New Brunswick. These determinations were extended to neighbouring provinces, and altogether 1075 observations were made with the instrument in New Brunswick, Nova Scotia, southern Quebec and southern Ontario. Definite relations have been found to exist between the gravity anomalies and geological formations in Nova Scotia and New Brunswick. Analysis of results in other provinces is not yet sufficiently complete to express a definite opinion.

Astrophysics

The type of work originally pursued with the 15-inch equatorial—radial velocities, determination of binary orbits, etc.—had long ceased to be profitable, by reason of the fact that the field of brighter stars had been practically exhausted, and the length of exposures required to obtain spectra of the fainter stars was prohibitive. The field of spectroscopy was therefore left to larger telescopes and attention was turned to the study of variables by the methods of photo-electric photometry. Considerable work along these lines was done in the earlier years of the period under review, but since the advent of the war, owing to lack of staff, the telescope has been idle except for the entertainment of visitors on open nights. Much the same is true of the photographic equatorial, with which a programme of photographic photometry had been followed. After the retirement and subsequent death of the officer charged with this work, which occurred shortly before the war broke out, this telescope also has been idle.

CURRENT RESEARCH

Meridian work

The programme at present under way with the meridian circle includes the Backlund-Hough stars and some others, together with a selected list of fundamental stars. Owing to difficulties enumerated earlier, observations of the sun and daylight stars have been discontinued, and the star positions resulting from the programme will follow the system of the fundamental stars.

Experimental work has been under way for some years, and is still continuing, on a modified type of gravity pendulum. Experiment and theory both indicate that, if pick-up and deposit of the gravity arm are both on the same side of zero, that is, if the resulting impulse is not central,

there is an optimum amplitude which depends on the position of impulse, and which give a minimum rate. If the amplitude is either less or greater than this the pendulum loses time. Consequently, if the amplitude is set to this optimum value, the rate is practically independent of small changes of arc. It also appears to be feasible to effect the re-setting of the gravity arm by photo-electric means, so that the pendulum will be free of electric contacts, and will do no work except the lifting of the gravity arm.

Solar physics

Work is along the lines followed previously, especially the spectroscopic measurements of solar rotation, wave-lengths across the solar disc, solar distance and solar variation in relation to terrestrial phenomena. The results of work of previous years are also being reduced, discussed and prepared for publication.

Terrestrial magnetism

In addition to the regular re-occupation of repeat stations for secular change, the survey is being extended into new territory, especially in northern areas. During the past winter an observer accompanied exercise Musk-Ox and gathered magnetic data along the route ; he also gained valuable first-hand knowledge regarding the operation and behaviour of magnetic instruments at low temperatures. In the same connexion, a temporary observatory, where eye readings of the magnetic elements were made, was established at Baker Lake, N.W.T., and operated for the duration of the exercise to control observations made along the route.

Considerable progress has been made in correlating magnetic disturbances at fixed observatories and field stations. Investigations are being undertaken to ascertain the effective radius from a fixed observatory at which disturbance corrections apply to results at field stations. At the present moment attention is particularly directed to control for vertical force observations made in mining areas. Co-operation is also being established with the Canadian Radio Wave Propagation Committee in an endeavour to correlate magnetic and ionospheric data.

Gravity

The previous policy of extending the gravity survey, especially in northern regions, is being followed. During the present season it is planned to establish new stations in the northern country, in continuance of similar work in 1945.

Seismology

Maintenance of the seismograph stations enumerated previously, including reporting of the data to co-operating institutions, is being regularly continued. The study of the records of the Cornwall earthquake is being carried through, and a final report will be issued shortly. The rockburst records and notes are being put in final form, and a report is being prepared giving a summary of the work done and the conclusions drawn. A project is now under way to have specimens of rock from typical Canadian mines

taken to Washington, where the basic experiments on the microseismic method will be again carried out under the supervision of a seismologist, a geologist and a radio engineer from Canada.

Applied geophysics

The proposed programme for the present season includes the purchase of a gravity meter and the rehabilitation of one existing vertical magnetometer. With these instruments it is proposed to run a gravimetric and magnetic traverse across the southern part of the prairie provinces from the eastern boundary of Manitoba to the foothills of Alberta. It is hoped that this will assist in throwing additional light on the geological structure of these areas, and perhaps indicate regions where there are possibilities that oil bearing structures may exist.

PROPOSED FUTURE RESEARCH

In future years it is hoped that all present activities will be continued and expanded, with whatever modifications may be found necessary or advisable. One of the problems that must inevitably be faced before very many years, so far as telescopic work is concerned, is that arising from proximity of city lights and smoke. While, now that the war is over, the soft-coal smoke nuisance may be abated, conditions will grow worse as time goes on, and eventually the removal of the telescopic equipment from close proximity to the city must be considered. In the meantime, as remarked above, present activities will be continued and expanded.

The present meridian circle programme will not be completed for several years, and it seems likely that the time service will continue much along present lines, with whatever improvements and extensions are found possible or necessary. One improvement is looked forward to. Tentative plans have been informally discussed for the design and construction of a photographic zenith tube for determination of time, to be housed in a small separate building. This should remove one of the difficulties faced at the moment and markedly improve the service.

It is proposed to initiate a much closer liaison than in the past between solar physics and the astrophysical work carried on with the 15-inch equatorial and the photographic equatorial. These lines of work are closely allied, and closer co-operation under one supervising astronomer will be to the advantage of both. It is expected to resume work with the equatorial instruments shortly. Photometric programmes will be resumed, and the work will probably be expanded to include meteor research.

It is proposed in the near future to establish a geophysical station at Churchill. The instrumental equipment would include recording magnetic instruments, seismographs and instruments for the measurement of atmospheric electricity and earth currents. Tentative plans also call for a similar station in Labrador or Northern Quebec, and possibly at other points in northern areas.

Present plans also call for further extension of magnetic and gravity surveys in Northern Canada ; indeed such further extension has begun

already. Eventually the whole of the northern country should be covered by a network of magnetic stations, whose occupation is repeated at intervals for control of secular variation and to enable the construction of accurate magnetic maps for airborne transportation. Gravity stations should likewise be distributed over the whole area. It would then be possible, with the gravity and magnetic stations as calibration points, to make more detailed surveys with gravity meters and field magnetometers, as might seem desirable for the delimitation of underground structure in any particular area from time to time.

SCIENTIFIC RESEARCH WORK CONDUCTED BY THE HYDROGRAPHIC SERVICE OF CANADA

THE Hydrographic Service of Canada, under the administration of the Surveys and Engineering Branch of the Department of Mines and Resources, Ottawa, is responsible for the charting of the coastal and inland waters of Canada, the analysis of tidal and tidal current phenomena and the investigation of water surface fluctuations of the Great Lakes–St Lawrence Waterway. The scientific work conducted begins with actual field surveys and is completed by the production of data in the form of nautical charts, tidal and current publications, water-level bulletins and a number of special reports. Supplementary to the regular work of the Service are the following investigations undertaken in recent years. Many are of a continuing nature.

HYDROGRAPHY AND NAVIGATION

SEA AND AIR TEMPERATURES ON NORTH ATLANTIC ROUTES TO LIVERPOOL

During the war, when ships equipped with artificial refrigeration were scarce and continually becoming more so, it was necessary to ship fresh foods to Britain in ordinary tramp vessels without the benefit of mechanical refrigeration of any kind. Main factors depended on to prevent cargo spoilage were low sea and air temperatures. To ascertain which of the direct sea routes from United States and Canadian ports to Liverpool provided maximum natural refrigeration the Canadian Department of Agriculture in conjunction with the Canadian Produce Association, requested this Service to prepare a report for the guidance of shippers.

Accordingly, bathythermal and other data were obtained from various sources and from these were compiled sets of chartlets showing, for each month of the year, the following information :

Sea and air isotherms in the North Atlantic, Gulf and River St Lawrence.

Official (seasonal) ocean tracks and distances from Canadian and United States ports to Liverpool.

In supplementary pages to the report sea temperatures on the different routes are analysed for comparative purposes. The results are then summarized in a comprehensive graph which indicates the considerable advantage of using the Canadian tracks to obtain maximum natural refrigeration. As opportunity permits, sea and air temperatures on the Hudson Bay route will be similarly investigated and added to the report.

WATERPROOFING OF SEA CHARTS

Experiments were carried out to develop a process for waterproofing navigation charts for practical use on an open bridge of a ship where charts are exposed to wet weather and salt spray. Stipulations were that

charts so treated must retain their original exact dimensions, that their pencilling, inking and erasing properties be unaffected, and that the original chart printing retain full density and sharpness. Charts treated with waterproofing chemicals and by different processes were subjected to actual working conditions at sea. The work was conducted jointly with the National Research Bureau and the Department of National Defence, Ottawa.

Tinting of nautical charts for night-light vision

Experiments were conducted to develop chart printing colours which would provide maximum visibility under the peculiar red lighting conditions used in ships' chartrooms during the war. Particular shades of blue, buff and magenta were found suitable and it is proposed to continue their use in peacetime.

Use and development of modern surveying devices (echo-sounder, radar, loran)

This Service early adapted the use of echo-sounding instruments for use in hydrographic work conducted from small launches. Large scale plotting graph and a high degree of accuracy is required.

It is proposed to install a plan-position-indicator type of radar on the Canadian Hydrographic Ship *Acadia* during the season of 1946. The purpose of this will be the study of its application of navigation and hydrographic operations. It is expected that this type of installation will be of more use for navigation than for surveying.

The National Research Bureau is prepared to design and build special loran type apparatus for offshore surveying and to co-operate with this Service in experiments at sea. It is felt that there are excellent prospects for success with this scheme.

Hydrographic surveys of the continental shelf

A major scientific undertaking contemplated for the future is the charting of the marginal seas of Canada out to the edge of the continental shelf. Indications are that the whole area is traversed with deep, well-defined gulleys extending in from the outer continental slope. From this shelf rise some of the greatest fishing banks in the world, but the only existing charts of the region are quite inadequate for present day requirements of either fishing, navigation or other development. An accurate, comprehensive survey will involve the use of the above mentioned devices of echo-sounding, radar, loran and also modern bathythermal instruments.

TIDAL AND CURRENT INVESTIGATIONS

The work of the Tidal and Current Division is concerned with obtaining data in regard to tides and tidal streams ; prediction of tides and currents and the preparation of annual tide and current tables ; determinations of mean sea level and low water datum planes ; study of methods of observing tides and currents and of reduction of tidal and current observations ; development of instruments and devices for recording tides and currents and the study and research in tidal phenomena in general.

Tides

Analysis of tidal records obtained from primary tidal stations determine the long term variations in tidal ' constants ' for the improvement of tidal predictions, a matter of special interest to the Tidal Institute and to the International Hydrographic Bureau. Information with regard to the time of high and low tide, and the rise of tide in localities not already dealt with is obtained year by year for inclusion in the tide table publications.

Tidal streams

These are charted and reports concerning them are published. The ' Tidal and Current Charts ' for the St Lawrence Estuary is the result of the most recent work and, on the west coast, the tidal streams through Seymour Narrows were surveyed in 1945. From stream velocities measured, predictions for the rates of the flood and ebb through the passage are published.

Temperatures and densities of the sea

Incidental to the work of surveying tidal streams, temperatures and densities of the water are systematically taken at different depths. These data, in addition to the information on water circulation are of value to the Biological Board of Canada and other authorities.

Mean sea level

Mean sea level as deduced from records of primary tidal stations is the basis of the Canadian geodetic system of levels. Monthly and annual values are determined at all tidal stations.

PRECISE WATER LEVEL INVESTIGATIONS OF INLAND NAVIGABLE WATERS

Scope of operations

The fluctuating water levels of the Great Lakes–St Lawrence Waterway are continuously recorded by self-registering gauges at some forty-seven locations. Government and industrial services are provided with co-ordinated precise water level data and analysis as basis for national and international studies conducted by Lake Superior Control Board, St Lawrence Deep Waterways, Regulation of Lake St Francis, Interdepartmental Water Levels Board and others.

Tides and lunar influence on the Great Lakes

Research was started on this subject some years ago but had to be set aside for more pressing activities during the war. The results obtained indicate that spring and neap tides occur on the days of the moon's phases without several days' lag as is common in ocean tides. Lunar influence is discernible from water level records obtained at all permanent gauge locations, but the amplitudes in no case exceed 0·16 foot at spring tides or 0·08 foot at neap tides.

Tilting or crustal movement

This subject is under more or less study at all times as it affects relative values of elevation throughout the whole of the Great Lakes Basin. The tilt is approximately north-east to south-west. Research to date indicates that the rate of tilt is approximately 1·00 foot per 100 miles per 100 years. Geological data such as old beaches establish the amount of over-all tilting in past ages, but do not indicate the present rate.

Seiches or irregular oscillations

Seiches with ranges up to six inches are always present in each of the Great Lakes. In Lakes Superior and Huron the seiche ranges increase within a few hours to as much as five feet when the period of time between a high and low, or the reverse, may be as short as ten minutes. Study of these phenomena relate the major actions to sharp and deep changes in atmospheric pressure when a storm front is either forming or passing over the lake. The small, and more or less continuous, seiching can be attributed to ordinary variations in pressure over the whole expanses of water.

This Service conducted a detail study of seiches entering the St Mary River from Lake Superior in which 321 seiches were used as the basis of deduction. Results indicated that, on the average, the vertical range doubled in the fifteen miles to above the canal lock at Sault Ste Marie. Also that the average time for an oscillation to move down the fifteen miles of river was 51 minutes. Other studies show that minor seiches along the open shore build up in bays and river mouths to major range.

Factors affecting rise and fall of lake and river levels

Evaporation is the major factor governing the balance between precipitation and run off. Research on this subject is based on forty-five years of detailed data and final deductions indicate that 66 per cent. of the precipitation on the Great Lakes Basin is lost through evaporation, and only 34 per cent. maintains the flow out of Lake Ontario. A similar study for the Ottawa River Basin shows a loss of only 45 per cent through evaporation. The larger loss through evaporation over the Great Lakes is attributed to the areas of those lakes being subject to loss at all times, even during the winter months when the small lakes in the Ottawa basin are under an ice cover.

ORGANIZATION OF RESEARCH IN RESPECT OF THE COLONIES

Memorandum prepared by the Colonial Office for the Commonwealth Scientific Official Conference

(Note : This paper is published by the kind permission of the Commonwealth Scientific Official Conference Working Party)

THE present is a peculiarly difficult time in which to describe the Colonial research organization, partly owing to the severe interruption in previous lines of development occasioned by the war, and partly owing to the fact that, as a result of the substantial provision for research made under the Colonial Development and Welfare Act of 1940–1945, considerable expansion and reorganization is being planned.

It may be useful, however, briefly to describe the pre-war arrangements and then to proceed to some account of the way in which plans are developing.

Provision for scientific research work in the Colonies themselves before the war are briefly indicated in Appendix 1 to this memorandum. (The details are taken from appendices to the Progress Report for 1942–1943 of the Colonial Research Committee, published by the Stationery Office in 1943 as Cmd No 6486.)

During the war, the progress of research in the Colonies has necessarily suffered a setback, owing to the importance of maintaining an adequate flow of scientists even for the existing institutions, the great difficulty of obtaining supplies and equipment, and the fact that many members of existing staffs had of necessity to be sent to other work of immediate relevance to the war effort. Even during the war, however, the outlook for the future was transformed by the passage in 1940 of the Colonial Development and Welfare Act of that year. Under that Act, apart from the annual provision of up to £5,000,000 for development and welfare, there was a specific provision of up to £500,000 a year for research and investigation. By the Amending Act of 1945, which provides a total sum of £120,000,000 for expenditure over the next ten years, the annual limit for research and investigation expenditure is raised to £1,000,000. Provision of this order clearly revolutionizes the possibilities of a research effort in relation to Colonial needs, and indeed it is no exaggeration to say that for the next few years at any rate the limiting factor is far more likely to be the supply of scientific workers than the availability of funds.

With these new funds available, it early became apparent that the research effort would need to be planned and considered with an intensity much greater than it had been necessary to devote to this matter in the past. In the past, research work in the various fields was reviewed, together with policy developments, by the various specialist advisory committees directly concerned, i.e., the Colonial Advisory Council of Agriculture,

Animal Health and Forestry, the Colonial Advisory Medical Committee and so on. The planning and oversight of the new research effort, however, constitutes a volume of work so great as to necessitate the establishment of separate and independent bodies to consider and advise on the planning and administration of research.

As a first step, the Secretary of State for the Colonies set up in 1942 the Colonial Research Committee, under the chairmanship of Lord Hailey, the members of that Committee at the date of the presentation of the Progress Report above referred to being as follows :

Sir Edward Appleton, Secretary of the Department of Scientific and Industrial Research.
Mr A. M. Carr-Saunders, Director of the London School of Economics.
Sir Hubert Henderson, Economic Adviser to the Treasury.
Professor A. V. Hill, Secretary of the Royal Society.
Dr W. W. C. Topley, Secretary of the Agricultural Research Council.

The Colonial Research Committee, realizing that war conditions would make the immediate initiation of new research projects difficult if not impossible, decided to devote their time to a review of existing provisions, and of the organizational and other needs if the best use was to be made of the new funds made available. For this purpose they called for, or had submitted to them, statements regarding the needs of research in the broad fields of agriculture, animal health and forestry, the social sciences, medical research, geodetic and topographical surveys, geological surveys and meteorological matters. They also considered such matters as the terms of service of scientific workers in the Colonies and the very important matter of the maintenance of liaison with scientific work done in the Dominions and elsewhere. In this latter connexion, they had the advantage of consultation with representatives of Dominion science in the persons of Brigadier B. F. J. Schonland, Dr Marsden, Dean C. J. Mackenzie and others.

In addition to this process, and from slightly different sources, there came into being, in 1943, a Colonial Products Research Council, of which the Chairman is Lord Hankey, and the Director of Research, Dr J. L. Simonsen, the function of which is to arrange for fundamental and other studies on the properties of Colonial raw materials with a view to their better utilization in industry.

As a result of the reviews considered by the Colonial Research Committee, it was decided to create separate and independent organizations to deal with the various major fields of research. These have now virtually all been created, and they are as follows :

Colonial Social Science Research Council
Committee for Colonial Agricultural, Animal Health and Forestry Research
Colonial Medical Research Committee (created jointly by the Secretary of State for the Colonies and the Medical Research Council).

In addition, there was created during this period a Colonial Fisheries Advisory Committee which at the present stage of Colonial fisheries development considers research matters as well as matters of policy and

administration. There is given in Appendix 2, in diagrammatic form, a statement of the various bodies which advise the Secretary of State for the Colonies with regard to various fields of research.

Economic research is catered for by the establishment of a Research Sub-Committee to the Colonial Economic Advisory Committee, liaison being maintained with the Colonial Social Science Research Council by the fact that the chairman of that Research Sub-Committee, Professor Arnold Plant, is a member of the Social Science Research Council. Liaison between these bodies and the Colonial Research Committee itself is achieved by the existence of common membership and otherwise. The various specialist bodies are directly advisory to the Secretary of State and (in the case of the Colonial Medical Research Committee) to the Medical Research Council of the United Kingdom as well.

The functions of the Colonial Research Committee are of a co-ordinating nature, and relate to questions of general policy and of the broad allocation of finance, rather than to the scrutiny in detail of schemes prepared by, or submitted to and receiving the support of, the specialist body particularly concerned.

In addition to these main bodies, and their immediate sub-committees, there exists a series of *ad hoc* committees on various special topics, including the Tsetse Fly and Trypanosomiasis Committee, Land Tenure Panel and the Locust Research Centre, which is administered by an interdepartmental committee in which the Colonial Office necessarily plays a leading part.

Broadly speaking, the function of these major committees is, as indicated, not executive, in that they do not have funds at their immediate disposal, but advisory to the Secretary of State, who, in accordance with the provisions of the Colonial Development and Welfare Act, is empowered, with the concurrence of the Treasury, to make schemes to enable specific research projects to be undertaken. These schemes may range from a few hundred pounds to enable an expert to visit a Colony for a specific purpose, to the provision of many thousands for the establishment and staffing of research institutes over a period of years. In practice, the voice of the various specialist committees, and of the Colonial Research Committee, is so great as to be virtually authoritative.

The fact that these central bodies exist does not imply that, in contradistinction to the past, all research work in the Colonies will, if financed from funds provided under the Act, be rigidly subject to central control. It is open to the Secretary of State, on the advice of the appropriate bodies, to make grants to other institutions, or to Colonial governments, having as conditions a degree of supervision which may be remote and general rather than close and detailed. The procedure is in fact entirely flexible, and the research committees, on which leading scientists are very largely represented, are normally anxious that, once the right man has been put in the right place, he should be left as free as possible to work out his own scientific salvation. Rather than attempt any centralized control, the policy is to choose the best men possible, to provide them with all possible facilities and access to advice and information, and leave them free to work out their own programmes and techniques.

A special word will perhaps be appropriate regarding the procedure

followed by the Colonial Products Research Council. That body has not as yet attempted to set up any central laboratory, but has of set policy endeavoured to arrange for research work in specific problems to be farmed out to the university or other laboratories best qualified to deal with it. By this means, it is hoped to spread a knowledge of and an interest in Colonial problems as widely as possible in this country and elsewhere and, broadly speaking, to encourage and support university and other departments in further and more detailed studies on subjects which are of interest to those departments and of importance for the Colonies. It may, however, be mentioned that it has been decided to set up, under the auspices of the Council, a Colonial Microbiological Research Institute with headquarters in Trinidad, of which the first Director is Dr A. C. Thaysen, lately of the Chemical Research Laboratory of the Department of Scientific and Industrial Research.

It may also be of interest to refer to a scheme instituted at the recommendation of the Colonial Research Committee, with the object of bringing United Kingdom and Dominion scientists into the Colonial fields for a time even though they may not choose to spend their whole careers there. This is the Colonial Research Fellowship scheme, which has been made widely known in British and Commonwealth universities, etc., under which scientific workers of some experience may be given two-year fellowships to enable them to pursue studies, of their own choice, in the Colonies. The object is thereby to secure good work on problems of Colonial interest and to create for the universities a body of scientists who have seen Colonial problems at first hand and who will thereby in future be able to maintain and to inculcate a lively interest in those problems.

A particular problem to which the Colonial Research Committee have been giving attention is that of the terms of service of scientific workers. Before the war, the normal practice in respect of government scientific work was to appoint workers on the normal Colonial service terms. Under these terms, a worker could only leave the Colonies at the expense of loss of his pension rights, and this fact tended to deter many potential workers from going to the Colonies and, moreover, to keep others there after their interest in the problems available on the spot had been exhausted. In consequence, the Colonial Research Committee have recommended that scientific research workers should normally be recruited on terms analogous to, and interchangeable with, the F.S.S.U. system obtaining in the universities, and this system, it may be noted, has now also been adopted for the United Kingdom Scientific Civil Service (see the White Paper on the Scientific Civil Service, Cmd No 6673).

In this brief survey, some account has been given of the present organization, particularly the centre, and of future plans. There remains yet to be solved one central but exceedingly difficult problem of peculiar moment for Colonial research owing to the terms of the Act from which its main financial sinews are derived. That Act provides funds for research and investigation, as part of a larger provision for Colonial development and welfare. It is therefore extremely important that the research effort should be planned and in the broadest sense related to the plans for development, and further, that full use should be made of this provision to enable the necessary investigations to be conducted to permit of the efficient and in

the broadest sense scientific framing of those plans themselves. To some extent this is being done by the adoption, on the recommendation of the Colonial Research Committee, of comprehensive plans for a centralized geodetic and topographical survey of the Colonies, under which it is proposed to complete the major triangulation of the Colonies, and half of the topographical mapping of their area, within a period of ten years. Furthermore, plans are in existance, though not so far advanced, for a centralized geological survey, which, on the basis of maps provided by the geodetic and topographical survey, would concentrate on the mapping of geological resources, leaving as a general policy the more detailed and specific studies required for special purposes to be dealt with by existing staffs. These provisions, though exceedingly important, only go some part of the way, and it remains to arrive at an entirely satisfactory means on the one hand of ascertaining which investigations, of all kinds, are more required for development planning, and on the other of the investigational and research work most required for the carrying out of existing plans.

APPENDIX 1

1. Agricultural research

(*a*) *West Indies*

Imperial College of Tropical Agriculture, Trinidad (chemistry, soil science, plant breeding, low temperature research). Financed by Imperial funds, Colonial governments, private sources and endowments.

West Indian Central Sugar Cane Breeding Station (genetics and plant breeding) in Barbados. Financed by Barbados, Jamaica, Trinidad and Leeward Islands.

Empire Cotton Growing Corporation Station (genetics and plant physiology) in Trinidad and St Vincent. Financed by levy on industry.

(*b*) *Africa*

Cacao research station at Tafo in the Gold Coast. Financed by government.

Oil palm research station at Benin, Nigeria, to serve all West Africa—in embryo. To be financed by Colonial Development and Welfare funds.

East African Research Institute at Amani (botany, ecology, biochemistry, entomology, plant pathology, plant breeding, soil science). Financed by East African Governments and Colonial Development and Welfare funds.

Coffee research station at Lyamungu. Government and Colonial Development and Welfare funds.

Sisal experimental station at Mlingano, Tanganyika. Financed by cess and Colonial Development and Welfare funds.

Coffee experimental team at Nairobi. Financed by cess.

Tung oil cultivation station in Nyasaland.

(c) *Mediterranean and Middle East*

Agricultural Research Station at Rehoboth, Palestine. Financed by Jewish Association.

(d) *Ceylon*

Tea Research Institute. Financed by cess on industry.

Rubber Research Institute. Financed by cess on industry.

Cocoa-nut Research Institute. Financed by cess on industry.

(e) *Mauritius*

Sugar Experimental Station. Financed by cess on industry.

(f) *Malaya*

Rubber Research Institute. Financed by cess on industry.

In addition to the above specific institutes, much experimental work, some of it of great importance, but too diverse to be adequately summarized, has been carried out in the past by the staff of the various Colonial Agricultural Departments.

2. Medical research institutes and schools of medicine

(a) *West Indies*

Government Medical Research Laboratories in British Guiana. Trinidad and Jamaica.

(b) *Africa*

Yaba, Nigeria. Research laboratory and School of Medicine, Financed by Colonial Government.

Accra, Gold Coast. Government Medical Laboratory.

Freetown, Sierra Leone. Sir Alfred Jones Laboratory under the aegis of the Liverpool School of Tropical Medicine (in abeyance).

Nairobi, Kenya. Medical Research Laboratory. Financed by Kenya Government.

Mulago Medical School, Makerere College, Uganda. Financed by Colonial Governments, fees and endowment.

Medical laboratory at Kampala, Uganda. Financed by Colonial Government.

Yellow Fever Research Institute at Entebbe, Uganda. Financed by Rockefeller Foundation with small Colonial grant.

Medical laboratory at Dar-es-Salaam, Tanganyika. Financed by Colonial Government.

Biochemical laboratory at Dar-es-Salaam. Financed by Colonial Government.

(*c*) *Mediterranean and Middle East*

Malta. University Medical School. Financed by Colonial Government.

Palestine. Government Medical Research Laboratories.

Medical Research Laboratory attached to Hebrew University at Jerusalem.

(*d*) *Ceylon*

Medical College. Financed by Colonial Government.

Department of Nutrition Research. Financed by Colonial Government.

(*e*) *Mauritius*

Government Medical Research Laboratory.

(*f*) *Malaya*

King Edward VII College of Medicine at Singapore. Financed by Colonial Government and fees.

Institute of Medical Research at Kuala Lumpur. Financed by Colonial Government.

(*g*) *Hong Kong*

University and College of Medicine. Financed by Rockefeller grant, endowment and Colonial Government.

(*h*) *Pacific*

Medical School at Suva, Fiji. Financed by Colonial Government.

In addition work of great importance for Colonial medical research is done at various institutions in this country including the following :—

London School of Hygiene and Tropical Medicine
Liverpool School of Tropical Medicine
Edinburgh School of Tropical Medicine
Wellcome Bureau of Scientific Research (Yellow Fever)
British Empire Leprosy Relief Association.

3. VETERINARY RESEARCH STATIONS

(*a*) *Africa*

Nigeria. Laboratory at Vom. Financed by Colonial Government.

Gold Coast. Small laboratory for manufacture of vaccines at Pong Tamale. Financed by Colonial Government.

Kenya. Research Station at Naivasha (nutrition, genetics). Financed by Colonial Government.

East African Research Institute at Kabete (animal pathology). Financed by East African Governments.

Kenya Research laboratory at Kabete (all subjects). Financed by Kenya Government.

Northern Rhodesia. Laboratory at Mazabuka. Financed by Colonial Government.

Nyasaland. Small diagnosis laboratory at Blantyre. Financed by Colonial Government.

Tanganyika. Shinyanga Research Laboratory of the Tsetse Department.

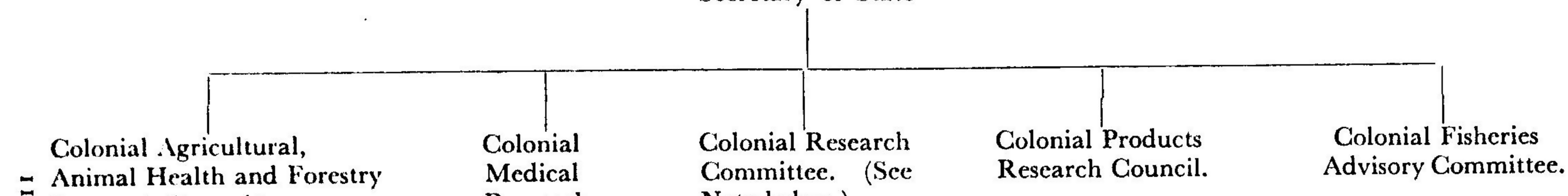
(*b*) *Mediterranean*

Palestine. Well-equipped laboratories at Jerusalem. (All branches.)

The above include all the veterinary research stations established in the Colonial Empire up to the war.

APPENDIX 2

ADVISORY BODIES (RESEARCH)



Note.—All the various research bodies listed above are directly advisory to the Secretary of State, who, however, looks to the *Colonial Research Committee* to advise him on general questions of research policy and on the allocation of the research funds provided under the Colonial Development and Welfare Act of 1940.

ORGANIZATION OF SCIENCE IN INDIA AND SOME OF THE PROBLEMS IN APPLIED SCIENCE

By Sir SHANTI S. BHATNAGAR, O.B.E., F.R.S.
(Director, Scientific and Industrial Research, India)

THE Government of India have lately played an important part in fostering scientific activity in India. Apart from the fact that a major proportion of the funds of the universities are provided by either the Central or Provincial Governments, a large number of the institutions taking active part in scientific or industrial research are either partly or wholly maintained through government grants. Although substantial contributions have been made by benefactors to public funds in India, it is nevertheless true to say that neither the philanthropists nor the business men in India have been fully conscious of the necessity of providing science and technology with adequate funds. As a result we see in India more dependence on government sponsored research than, perhaps, in any other country. This forms a sharp contrast to the conditions in the U.S.A. where private bequests have for long supported a large proportion of research institutions. Benefactions associated with names such as Rockefeller, Guggenheim, Carnegie are of international magnitude. In the U.K. while public donations have not been as numerous as in the U.S.A., still national funds like the Royal Society's 1851 Exhibition, or private bequests like the Leverhulme Studentships, the Beit Fellowships and the more recent I.C.I. Fellowships have gone a long way to support scientific work. In India too, benefactions like those of the Tatas are household words and one has only to think of the Tata Cancer Hospital, the Tata Institute of Fundamental Research, the Tata Institute of Social Sciences, the Tata Scholarships Trust and the Tata donations to the National Chemical and the National Metallurgical Laboratories to realize their wide sympathies. But, generally speaking, the public conscience is not yet fully awake to the needs of the country in the matter of scientific research. This is rather unfortunate but the situation is bound to improve as industry becomes more research minded. In considering the present organization of scientific work in India, it will be useful to bear this background in mind. It may be said that while the Government of India have been conscious of the growing importance of science, their attitude to scientific activity has, till very recent years, been more of benign condescension rather than of benevolent encouragement. Even now the funds allotted for scientific research are very meagre.

SURVEY OF INDIA

Perhaps the earliest scientific activity in India was the inauguration of the *Great Trigonometrical Survey of India* in 1800. Its earlier work was

directed towards triangulation and map printing in both of which a high standard has been maintained throughout. Prediction and publication of Tide Tables for Indian Ocean ports has formed an important part of the Survey of India's work for some time. The Survey has to its credit valuable geodetic work especially on gravity and magnetic surveys, though this part of the Survey's work needs to be considerably extended. Unfortunately the work of the geodetic branch was shut down as an economy measure at the beginning of the last war, but it was later revived under the name of *War Survey Research Laboratory*. The Survey of India is under the control of the Surveyor General of India, who is drawn from military ranks, and the organization has primarily existed to serve military needs for detailed and accurate maps. Considerable use has, however, been made of the Survey's data for irrigation projects and mineral surveys.

Geological, botanical and zoological surveys

The *Geological Survey* is by far the largest of the Surveys, and has done useful work within the limits set by its meagre financial resources. A Mineral Utilization Branch was added to undertake exploratory work on mineral deposits with a view to determining their commercial utility. This has recently been replaced by a Board for Mineral Development. Considerable additions to the activities of this Survey are, however, envisaged in the plans of expansion now under consideration since war time shortage of minerals brought into prominence the very incomplete knowledge of India's mineral resources.

The *Botanical Survey of India* was established in 1889. Its activities are at present confined to the maintenance of the Botanical Gardens and the botanical section of the Indian Museum and to work in connexion with cinchona cultivation. Retrenchments made in 1931 stopped practically all field work of this Survey.

The *Zoological Survey* was established in 1916 through the amalgamation of the Zoological and Anthropological sections of the Indian Museum. Its activities, too, have suffered much for want of funds. Practically no field work could be done since the retrenchment of its grants in 1931, but a reorganization scheme is now under consideration by the Government of India. Recently fishery research has found a place within the scheme of this Survey.

Meteorological department

The *India Meteorological Department* has a large organization which collects data from some 500 weather observatories dotted all over the country. There are a number of small observatories for wind measurements and two well provided laboratories at Poona and Delhi for upper air work. The Department maintains a storm warning service for coastal shipping and issues weather forecasts for aviation. During the war, requirements of the air forces necessitated large increase in this part of the Department's work. Agricultural meteorology is a notable addition to the Department's activities. The Solar Physics Laboratory at Kodaikanal

and the Magnetic and Seismological Observatories at Bombay are under the control of this Department. A large section is devoted to the manufacture and testing of meteorological measuring instruments. Most of the work of the Department is of purely routine character and only recently some attention has been given to research. A scheme for the expansion of the Department is, however, before the Government of India.

Public health

Public health organizations in India may be traced back to 1859 when a Royal Commission appointed to report on the sanitary state of the army recommended a 'Commission of Public Health' for each Presidency to supervise and improve the sanitary conditions of the general population and the cities, to prevent epidemics and to construct drainage, and water supplies, etc. A Sanitary Commissioner and Statistical Officer was appointed in 1869, but in 1888 this office was merged into that of the Director General, Indian Medical Service who continues to be the technical head on all medical questions in India. The Central Government's combined Department of Education, Health and Lands was recently divided into three separate Departments.

The Central Advisory Board of Health constituted in 1937 has representation of provinces and of the Indian States. Though advisory in capacity it has served the useful purpose of stimulating the development of provincial organizations to deal with problems like nutrition, malaria, school health, etc.

Medical research in India has, in the main, been concentrated at certain special institutes outside the medical colleges and universities. The more important of these special institutes which form part of the research activity of the Indian Medical Service are :

(*a*) The Central Research Institute, Kasauli.
(*b*) The School of Tropical Medicine, Calcutta.
(*c*) The Haffkine Institute, Bombay.
(*d*) The King Institute, Madras.
(*e*) The Malaria Institute of India, Delhi.
(*f*) The Drug Research Laboratory, Jammu (Kashmir State).
(*g*) The All-India Institute of Hygiene and Public Health, Calcutta.
(*h*) The Nutrition Research Laboratory, Coonoor.
(*i*) Pasteur Institutes at Kasauli, Shillong and Coonoor.

Grants for research and salaries of research staff are provided by the Indian Research Fund Association. While this scheme has resulted in some good research work being done, it has been adversely criticized among others by Professor A. V. Hill for 'isolating medical education and the clinical work of teaching hospitals from all contact with research.' The Indian Research Fund Association plays a somewhat similar rôle to the United Kingdom's Medical Research Council. But unlike the latter, the Indian organization suffers from shortage of funds. Its activities, in consequence, have been very limited.

Agriculture forms the backbone of India. Besides food crops, India grows a number of crops of great economic value. The present food shortage is bringing home to most people the great importance of agriculture not only to the well-being of the people but for their very existence. The United Nations' Conference on Food and Agriculture had for one of its objectives the improvement in the level of nutrition and the raising of the standard of living of the people. It is thus India's obligation and primary responsibility to see that at least its own population have the food needed for health and nourishment. Besides food, a number of agricultural by-products have vast industrial possibilities. Indeed, it has been shown that very considerable industrial development is possible in India based wholly on its agricultural and forest products. We have first to face the fact that the level of average production per acre in India is deplorably low for most of the crops. Four-fifths of the total cultivated area is still dependent on the vagaries of rainfall for successful crop raising. Agricultural implements are still primitive. Organic manures are scanty as most of the animal refuse is burnt due to fuel scarcity caused through want of feeder roads and services. Scientific control of pests and weeds is mostly unknown due to want of trained demonstration staff. India has no factory so far for manufacturing artificial manures although plans for putting up an ammonium sulphate factory at Sindri are taking shape. Even the bones of slaughtered animals have so far been largely exported through want of sufficient factories to treat them. All this goes to show how far agricultural practice lags behind scientific work.

India's central organization for agricultural research is mainly concentrated in the Imperial Council of Agricultural Research and the All-India Committees for Cotton, Jute and Lac. Recently a Central Tobacco Committee has been constituted which will have a research laboratory at Guntur. Plans are also being discussed for a Central Cocoanut Committee. Several of the provinces and states have got their own research organizations but most of the research programmes are co-ordinated by the Imperial Council of Agricultural Research.

The important central research institutes are :

(*a*) The Imperial Agricultural Research Institute, Delhi.
(*b*) The Imperial Veterinary Research Institute, Mukteswar and Izatnagar.
(*c*) The Imperial Dairy Research Institute, Bangalore.
(*d*) The Imperial Institute of Sugar Technology, Cawnpore.
(*e*) Sugar-cane Research Station, Coimbatore.
(*f*) Forest Research Institute, Dehra Dun.

The All-India Committees for Cotton, Jute, Lac and Tobacco are :

(*a*) *The Indian Central Cotton Committee* which derives its income from cess on raw cotton. It maintains a Cotton Technological Laboratory at Matunga, Bombay, and a sub-station at Indore in collabora-

tion with the Indian Institute of Plant Industry mainly for work on cotton genetics.

(*b*) *The Indian Central Jute Committee*, financed by the Central Government, maintains a Technological Laboratory at Calcutta and a farm at Dacca.

(*c*) *The Indian Lac Cess Committee* derives its income from a cess on the export of the lac and maintains a Technological Laboratory at Ranchi.

(*d*) *The Central Tobacco Committee* has recently been formed and a Tobacco Research Laboratory is being set up at Guntur.

While some excellent work has been done in India on agricultural research, it requires to be very greatly extended. The total sum spent on research in agriculture is estimated at Rs. 70 lacs annually (about £500,000). As Professor Hill has pointed out, this is less than what was being spent by Britain before the war for an agricultural area one-twentieth in size.

Forestry and fishery

Closely allied to agriculture are forestry and fishery. The Forest Research Institute at Dehra Dun possesses a first-rate herbarium and other facilities for research on all tropical forest plants and products. Equipment includes, besides laboratories, a pilot plant for the manufacture of paper from bamboo and machinery for timber testing and impregnating.

The food shortage in recent years and particularly the Bengal famine has directed attention to the development of fish as a supplementary food. Although fish has formed an article of food for long, the fishery industry in India was never approached from a scientific standpoint till very recently. There is still a lack of detailed knowledge about fisheries. Only a few of the provincial governments have fisheries departments and those that are in existence are inadequately staffed. Lack of trained personnel is another bottleneck. Plans for a Central Institute for Fisheries are already under way. Apart from research and experimental work, such an institute will have the responsibility of providing facilities for the training of personnel in the various branches of fishery work.

Scientific and industrial research

It is remarkable to note that while some of the scientific activities in India came of age many years ago, and some like the Geological Survey are nearing a century of existence, industrial research under the Central Government is hardly six years old. The formation of the Board of Scientific and Industrial Research in 1940 followed by the setting up of the Council of Scientific and Industrial Research in 1942 to control the activities of the Board of Scientific and Industrial Research and the newly created Industrial Research Utilization Committee, formed the first concrete steps taken by the Government to place industrial research on its feet in India. The need became manifest during the war when the demands of military departments coupled with scarcity of shipping threatened to throw the entire Indian industry out of gear. Not only did a number of materials get in acute short supply but the War Department wanted many

new things which they were unable to get from abroad. In the course of a few months, a research laboratory was set up in Calcutta ; and when Calcutta itself was threatened, it was transferred to Delhi, where it still shares lodgings with the laboratories of the Delhi University.

During the war the Council provided means of scientific liaison between the increasing military demands and the diminishing supply sources. The Council undertook numerous surveys of sources of raw materials and drew the attention of manufacturers to them. Apart from the work done at its own laboratories, the Council of Scientific and Industrial Research made considerable headway with scientific organization. For the first time it directed the attention of the scientific workers at universities and other institutions to industrial research. Twenty-two research committees were set up under the Board to draw up research plans and examine research schemes submitted by the universities and other institutions. It was realized early that workers in India were considerably handicapped due to want of authentic information on indigenous raw materials and resources. This led the Council to set up an organization for compiling a comprehensive *Dictionary of Economic Products and Industrial Resources* of the country. Volume I of this dictionary is going to be shortly published. A Journal of Scientific and Industrial Research was started and has already gained much popularity.

In 1942, the Council approached the Government of India with a post-war plan for the establishment for five national laboratories and research institutes. The scheme was approved of by the Government and active planning work for the following laboratories was started in 1943 :

(*a*) National Physical Laboratory
(*b*) National Chemical Laboratory
(*c*) National Metallurgical Laboratory
(*d*) Fuel Research Institute
(*e*) Central Glass and Ceramic Research Institute.

The National Physical Laboratory is to be located at Delhi, the headquarters of the Government of India ; the National Chemical Laboratory at Poona, near the industrial area of Bombay ; the National Metallurgical Laboratory at Jamshedpur, near the Tata Iron and Steel Works ; and the Fuel Research Station in the heart of coal fields area, at Dhanbad. Work on the construction of a Central Glass and Ceramic Research Institute has already been started at Calcutta. The schemes for the laboratories have been examined by experts in the U.K. and the U.S.A. and have met with their approval. Besides the above five laboratories, the Council have also approved schemes for—

(i) a Road Research Station at Delhi, and
(ii) a Building Research Station at Roorkee.

Both these research stations will, it is hoped, start functioning very shortly.

Industrial research in India has been considerably handicapped because of the absence of research organizations of the industry itself. India does not have any institutions of the type of the research associations of the

U.K. A few of the industries have research organizations of their own, the Tata Iron & Steel Co. has a large research laboratory at Jamshedpur besides being members of some nine research associations in the U.K. and the U.S.A. The Indian Jute Mills Association has a well-equipped research institute dealing mainly with problems relating to the manufacture of jute products. The Indian Tea Association maintains a research organization known as Tocklai Experimental Station at Cinnamara in Assam. Some of the chemical manufacturing firms maintain research laboratories whose main function is testing and development rather than research. A scheme for a textile research laboratory has recently been sponsored by the Textile Mills of Ahmedabad. The Bombay Cotton Mill-Owners' Association has made arrangements for solution of their research problems at the Department of Chemical Technology of the Bombay University to whom they make a substantial contribution.

Some of the industries developed during the war have made enormous profits. But large war-time profits do not necessarily mean sound development unless the industry is based on scientific lines. Of this there is very little evidence at least so far as some of the newer industries are concerned. The need for providing adequate scientific aid to industry is thus very urgent. Besides lack of research mindedness of the industry, another factor which has hindered the full application of science to industry in India has been the want of confidence on the part of the industry in the industrial policy hitherto pursued by the Government of India. This can be remedied only with a National Government at the centre. A very important decision, which may go a long way towards rousing interest in industrial research, has been taken this year by the Government of India. In the current year's budget proposals, provision has been made for revision of income tax rules which will permit exclusion of expenditure on research from assessment for income tax. The Council of Scientific and Industrial Research and the industry have both been pressing for this concession for some time and it is a happy augury that it has found acceptance at the hands of the Finance Department.

A very important rôle which the Council has fulfilled is that of maintaining liaison with the entire scientific activity of the country. The Council has gained confidence of the scientist and the industrialist alike, and its Research Committees have representation of science as well as industry. The Council has given research grants for fundamental work as well as for applied science and industrial problems, the only handicap so far has been the paucity of funds at its disposal.

Research for the fighting services

Research organizations in India for the fighting services are so far completely divorced from all civilian contacts. Scientific work for fighting services is under the control of the Master-General of Ordnance. The exigency of the war led to the appointment of a Scientific Adviser to the M.G.O. The lack of contact with other scientific work in India has tended to isolate the War Department from all the advantages that could be derived out of the scientific organizations that India possesses. The Director of Scientific and Industrial Research was frequently consulted on

specific problems and his laboratories were called upon to undertake research on substitute materials and special requirements. But the fighting services on the whole have depended upon their own resources. The Director of Scientific and Industrial Research has on several occasions drawn the attention of the authorities to the need for proper organization of scientific research for the fighting services in India and to the absence of liaison with scientific India. The Council of Scientific and Industrial Research maintains close liaison with all the scientific activity in India, but the Scientific Section of the War Department continues to be an exception.

Universities and research institutions

The universities in India and research institutions like the *Indian Institute of Science* at Bangalore and the *Indian Association for the Cultivation of Science* at Calcutta have done much to further the advancement of fundamental science. Those familiar with the facilities provided by the modern laboratories in America or Britain would find it hard to understand the handicaps that beset the scientific worker in India at every step. Lack of equipment, lack of accommodation, long hours of routine work due to insufficient teaching staff and finally the eternal want of funds are some of the problems that handicap science teaching and scientific research in Indian universities. These circumstances should not be lost sight of when assessing the work done in India. The Government of India have no machinery for making grants to universities and research bodies for scientific research. Since its establishment the Council of Scientific and Industrial Research has been allocating grants for research on applied science and also, though in a much restricted manner, for fundamental work. Whatever be the agency involved, the need exists for much larger research grants to universities and other research organizations.

Learned bodies

The oldest learned society in India is the *Royal Asiatic Society of Bengal* which was founded in 1784 in Calcutta by Sir William Jones. At a very early stage in India's contact with the West, this Society provided a common meeting ground between scholars of East and West. Literature, arts, history, philology, science—all came within the orbit of its learned discussions. The Royal Asiatic Society sponsored the *Indian Science Congress* which first met in 1914 and forms the Indian counterpart of the British Association for the Advancement of Science. Its annual session is held by rotation at different centres in the country and is widely attended by scientists. The Indian Science Congress Association is now a separate body though it owes allegiance to its foster parent.

The premier scientific body in India, the *National Institute of Sciences* came into being in 1935, as a result of the deliberations of a committee appointed for the purpose by the Indian Science Congress. The headquarters of the National Institute of Sciences has lately been transferred from Calcutta to Delhi, and the Institute has now been recognized by the

Government as the premier scientific body in India. Two other scientific bodies exist in India. They are the *National Academy of Sciences*, India, with headquarters at Allahabad and the *Indian Academy of Sciences* at Bangalore. Learned societies exist in India in almost all the scientific subjects : geology (1906) ; mathematics (1907) ; botany (1921) ; chemistry (1924) ; physics (1934) ; soil science (1934) ; physiology (1934) ; entomology, statistics, etc. The problem of India's vast distances is a great handicap to frequent intercourse and opportunity is taken by many of the societies to fix their annual meetings during the week of the Indian Science Congress Session in the first week of January every year.

Want of central co-ordination

Professor A. V. Hill during his visit to India in 1944 made a careful study of the scientific organizations in India. His critical report entitled '*Scientific Research in India*' contains a strong plea for a reorganization of science in India and for a central co-ordination of all research work that is being done under the control of the Central Government. Unlike the U.K. where most of research activity is co-ordinated by the Lord President of the Council through the medium of Research Councils in Medicine and Agriculture and the large organization of the Department of Scientific and Industrial Research, scientific research in India is dispersed over several Departments of the Central Government as below :

(*a*) *Health Department :* This Department administratively controls the Indian Research Fund Association and the various medical research units mentioned in the previous pages.

(*b*) *Agriculture Department :* Under the control of this Department, the Imperial Council of Agricultural Research awards research grants to Provincial and Central Institutions engaged in agricultural research. The various Committees on Cotton, Jute, Lac, etc., are also administratively under this Department. The Survey of India, the Zoological Survey and the Botanical Survey are also controlled by this Department.

(*c*) *The Posts and Air Department :* This Department controls the India Meteorological Department.

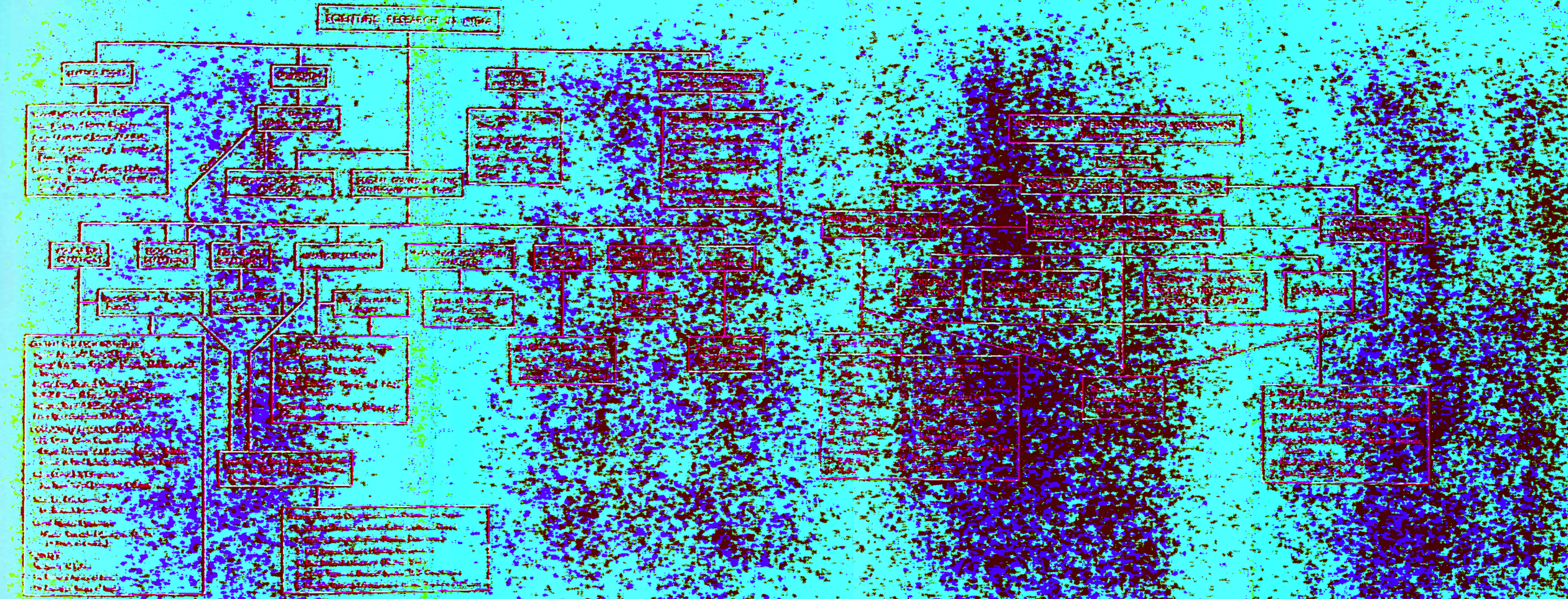
(*d*) *The Power, Mines and Works Department* recently separated from the Labour Department, has the Geological Survey of India under its administrative charge.

(*e*) *Planning and Development Department* has the Council of Scientific and Industrial Research under its charge.

(*f*) *Education Department :* This Department controls grants to universities and scientific institutes and looks after the training of personnel abroad.

As a result of Professor Hill's recommendation, the Government of India appointed a *Scientific Consultative Committee* with the Honourable Member in charge of the Planning and Development Department as its Chairman. This Committee consists of five official and five non-official scientists and is mainly concerned with laying down policy. The formation

of this Committee has improved matters so far as co-ordination goes, but the scientists have felt that the dispersal of research over a number of administrative departments is somewhat unsatisfactory and the best arrangement would be to place most of the research activities in the charge of one minister after the British pattern. In some cases, scientific institutions form administratively unimportant parts of large departments which have other duti esand preoccupations and as such cannot give sufficient attention to their needs and requirements. Professor Hill has considered this aspect in great detail and his recommendations on the reorganization of scientific research deserve to be implemented in full.



SURVEY OF INDIA

(Surveyor General)

Director, Map Publication	Director, Geodetic Branch	President, Survey Research Institute	Director, Southern Circle (Bangalore)	Director, Eastern Circle (Shillong)	Director, Frontier Circle (Murree)	Director, Central Circle (Dehra Dun)
Small scale maps compiled, special maps, lithographic work for Central Government Departments.	Field geodetic surveys, certain special surveys and maps. Instrument repair workshops, stores, air survey research (at present direct under Surveyor General). Letter Press publications and lithographic work connected therewith.	Research, except air survey and lithography. Observatories, tidal, magnetic and gravity surveys, metrology and levelling of high precision.	Regional directors, responsible for all surveys in their areas except geodetic and geophysical surveys, and responsible for publication of medium scale 'standard' maps of their areas, and maps required by local projects. The Director, Frontier Circle is also responsible for basic training.			

APPENDIX

SOME PROBLEMS IN APPLIED SCIENCE

1. Selected research schemes of the Indian Research Fund Association

Cholera

Cholera treatment inquiry (efficiency of Sulphaguanidine in Cholera treatment). (School of Tropical Medicine, Calcutta and King Institute, Madras.)

The statistical evaluation of anti-cholera inoculation in the Madras Presidency. (King Institute, Madras.)

Malaria

Insecticide and mosquito repellent inquiry. (Malaria Institute of India.)

Statistical inquiry into the methods of forecasting epidemic malaria. (Public Health Department, Punjab.)

Research on malaria. (Malaria Institute of India, Delhi.)

Nutrition

Nutrition inquiry. (Nutrition Research Laboratory, Coonoor.)

Ascorbic acid inquiry. (College of Science and Technology, Calcutta.)

Formation, function and variation of plasma proteins in health and disease. (Grant Medical College, Bombay.)

On the rôle of manganese on the biological synthesis of ascorbic acid. (Prince of Wales Medical College, Patna.)

Inquiry into factors affecting normal calcium metabolism in certain areas of Punjab. (Punjab University Institute of Chemistry.)

On the deterioration of vitamin A in liver oils, concentrates, and other preparations. (Indian Institute of Science, Bangalore.)

Relationship between vitamin B complex and tumour growth. (Tata Memorial Hospital, Bombay.)

Soya bean inquiry. (*a*) Tests of biological value of soya bean protein, (*b*) growth tests with soya beans, (*c*) human experiments with soya bean. (Punjab University Institute of Chemistry.)

Estimation of vitamin A activity of plant foods. (Punjab University Institute of Chemistry.)

Leprosy

Leprosy inquiries. (School of Tropical Medicine, Calcutta, and Lady Willington Leprosy Sanatorium, Madras.)

Plague

Plague inquiry. (Field trials of sulphathiazole and sulphadiazine.) (Haffkine Institute, Bombay.)

Pharmacology

Indigenous drugs inquiries. (School of Tropical Medicine, Calcutta, and Drug Research Laboratory, Jammu.)

Pharmacological inquiry. (Haffkine Institute, Bombay.)

Other inquiries

On filariasis. (School of Tropical Medicine, Calcutta.)

On filterable viruses. (King Institute, Guindy and Madras.)

On Kala Azar. (Pasteur Institute, Shillong.)

On the action of snake venoms and their constituents on the biochemical activity of the tissue cells. (University College of Science and Technology Calcutta.)

On typhus. (Haffkine Institute, Bombay.)

Infant and child morbidity and mortality in Calcutta. (All-India Institute of Hygiene and Public Health, Calcutta.)

Anaemia in pregnancy. (All-India Institute of Hygiene and Public Health, Calcutta.)

2. Selected research schemes of the Imperial Council of Agricultural Research

General

Mixed farming : rice and cotton tracts.
Desert farming (Sind and North-West Frontier Province).
Compost schemes.
Improvement in agricultural implements.
Crop cutting experiments : paddy.
Development of fodder crops and grasses.

Rice

Rice breeding schemes.
Breeding of salt resistant paddy.
Physiology of rice plant.
Nutrition of rice plant.
Vernalization and colochicine treatment of rice.
Diseases of rice.
Paddy insect pests.

Wheat and other cereals

Wheat breeding.
Wheat breeding for rust resistance.
Barley breeding for rust resistance.
Cereal rusts.
Wheat milling and baking tests.

Pulses and millets

Pulses and millets breeding.
Physiology of pulses.
Investigations on small millets.
Storage pests.
Gram wilt disease.
Gram pests.

Breeding schemes for oils seed crops like groundnut, rape, mustard, linseed, castor, sesamum, etc.
Pests and diseases of oil seed crops.
Storage of groundnuts.
Investigations on the effect of fertilizing conditions, variety and environment on the nutritive and vitamin value of groundnuts.
Bunchy top disease of groundnuts.
Manurial experiments with oilseed cakes.

Fruits

Manurial trials on citrus.
Survey of deciduous fruits of Kashmir State.
Fruit diseases like mango necrosis, citrus die-back, etc.
Cytogenetics of mango and banana.
Fruit preservation and canning.

Vegetables

Potato breeding. (Special research laboratories for hill stations.)
Potato storage pests.

Fibres and other crops

Linseed fibres.
Medicinal plants.
Betel leaf diseases.
Band disease of areca palm.
Investigation on clove cultivation.
Pepper diseases.

Soil science

All-India soil survey.
Minor trace elements in Indian soils.
Control of erosion.
Sewage farming.
Crop production by catalysis.
Nitrogen fixation.

Agronomy

Developmental research in dry farming.
Water requirements of crops.
Agricultural meteorology.

Entomology

Insect pests of stored cereals.
Control of insect pests by mercury vapour.
Morphological classification of the immature stages of caterpillar pests.
Physiology of termites.

Pathology

Virus diseases of crop plants.
Culture fungi.

Wool

Wool analysis, grading, washing, etc.

Poultry and eggs

Poultry breeding, husbandry, etc.
Poultry diseases.

Hides and skins

Control of warble fly pest.

Fish

Schemes of rural pisciculture.
Bionomics of fresh water fishes.
Biology of marine prawns.
Improvement of preserved fish.

Live stock

Artificial insemination.
Schemes of cattle improvement at various centres.
Goat and sheep breeding schemes.
Nutrition requirements of milch cows.
Determination of nutritive value of certain grasses and leafy fodders.
Bearing of nutrition on helminthic infestation in animals.
Schemes of cattle disease in investigation in different centres.
Investigation of mastitis, helminthiasis, etc.
Etiology of sheep diseases.

Dairy science

Various research schemes pertaining to dairy science.
Nutritive value and vitamin A content of ghee.
Chemistry and structure of ghee.
Natural preservatives for ghee.
Biochemical investigation of milk curds.
Standardizing the methods of analysis of milk and milk products.

3. Selected research problems investigated at the laboratories of the Council of Scientific and Industrial Research or under their research schemes

During the war the laboratories have been largely occupied with investigations on finding substitute materials to replace those in short supply and required for war purposes. Important industrial chemicals like formaldehyde, urea, aniline, nitrobenzene ; fatty acids like oleic and

stearic acid, etc., were in acute short supply and manufacturing processes for these were developed. Vegetable dyes were developed to replace imported coal-tar dyes. Shortage of sulphur led to the development of a process for utilizing low-grade Indian sulphur deposits. Efforts were made to manufacture radio components and scientific instruments on a limited scale. The following list gives some of the problems investigated :

Utilization of molasses in fermentative production of solvents and acids.
Recovery of potassium salts from molasses.
Industrial enzymes.
Yeast products.
National collection of type cultures.
Cytogenetics of yeast and fungi.
Exploratory work on synthetic dyestuffs.
Preparation of intermediates for dyestuffs industry.
Extraction of dyes from Indian vegetable sources.
Alpha-cellulose-bearing materials of India.
Manufacture of titanium dioxide from ilmenite and rutile.
Manufacture of phosphatic fertilizers from Indian phosphatic nodules.
Manufacture of barium chloride from Indian barytes.
Purification of low-grade sulphur.
Manufacture of organo-arsenical compounds.
Manufacture of melamine and urea from calcium cyanamide.
Manufacture of furfural.
Manufacture of drugs and pharmaceutical products from indigenous sources.
Preparation of glandular products.
Survey of aromatic plants of India.
Extraction of essential oils from certain aromatic grasses, roots and berries.
Utilization of essential oils as disinfectants.
Utilization of turpentine oil for the manufacture of turpeneol.
Utilization of neem oil and its bitter constituents.
Chemical studies and constitution of Indian plant products.
Manufacture of anti-malarials from indigenous sources.
Lubricants from vegetable oils.
Plastics from Indian vegetable oils.
Splitting and polymerization of vegetable oils.
Shellac plastics.
Laminated plastic products.
Drawn laminated mouldings.
Development of pressed jute boards.
Oil-silks and anti-gas cloth from indigenous resins.
Treatment of jute mill bobbins by resin impregnation.
Resin impregnation of wood.
Cork substitutes.
Waterproof paints.
Utilization of bhilawan nuts in the production of stoving enamels, paints, etc.

Development of rubber-lined equipment for chemical industries.
Tin lining compound from rubber latex.
Manufacture of high-grade gelatines from indigenous materials.
Manufacture of methanol from carbon monoxide and hydrogen.
Air-foam solutions from waste products.
Utilization of mica wastes.
Investigations on the radium contents of Indian minerals and mineral springs.
Extraction of rare earths from Indian monozite sands.
Manufacture of welding fluxes.
Welding fluxes for aluminium.
Low-temperature carbonization of Indian coals.
Desulphurizing of coal.
Physical and chemical survey of Indian coals.
Purification of Indian graphite and manufacture of electrodes.
Purification of low-grade sulphur.
Magnetic alloys.
Manufacture of electrical sheet steels.
Beryllium alloys.
Chemical properties of alloys in the liquid state.
Development of copper-silicon bronzes.
Development of aluminium-titanium alloys.
Problems connected with the manufacture of internal combustion engines.
Upper atmospheric research.
Ionospheric investigations.
Research on cosmic rays.
Convection phenomena in solar radiation.
Radiation equilibrium in the atmosphere.
Investigations on statistical and quality control methods.
Ultrasonic velocity in vegetable and essential oils.
Study of the crystalline structure of glass systems.
Manufacture of optical glass.
Manufacture of sintered glass.

ORGANIZATION OF SCIENTIFIC RESEARCH IN NEW ZEALAND

By Dr E. MARSDEN, C.M.G., C.B.E., M.C., D.Sc., F.R.S.

The six main scientific organizations interested are :

1. The University of New Zealand and its constituent colleges
2. The Department and Council of Scientific and Industrial Research
3. The Royal Society of New Zealand
4. Cawthron Institute (Agricultural), Nelson
5. Department of Agriculture
6. Medical Research Council (Department of Health)

1. UNIVERSITY. The University is organized as a Federal University with six constituent colleges :

(a) Otago University (retaining its original name), Dunedin
(b) Canterbury University College, Christchurch
(c) Victoria University College, Wellington
(d) Auckland University College, Auckland
(e) Canterbury Agricultural College (fourteen miles from Christchurch)
(f) Massey Agricultural College (100 miles from Wellington and 350 miles from Auckland)

The University itself is the central examining body and co-ordinator and has scholarship endowments but no considerable sums for research grants. Some five of the best science graduates are sent overseas on scholarships under its auspices each year in addition to others financed by funds at the disposal of individual colleges and by National Research Scholarships awarded through D.S.I.R. Thus there is a relatively heavy drain overseas of New Zealand's best selected scientific talent.

The special schools of medicine and dentistry are at Otago University ; the schools of engineering are at Canterbury College and Auckland.

There is a total of some 9,000 students attending the university colleges, and the teaching load is such that the university staffs have not so much time for academic research as is desirable, except in vacations. A Ph.D. degree is probably to be introduced this session.

Grants are made for research for special projects at the university colleges, e.g. £5,000 each was granted last year through D.S.I.R., each to Canterbury and Massey Colleges and Cawthron Institute and smaller grants to individual workers at other university colleges. In addition, certain research associations are situated and operated in co-operation with university colleges, e.g. Dairy Research Institute at Massey College (£23,000 p.a.), Wheat Research Institute (Christchurch), Division of

Industrial Psychology (Wellington), Wool Manufacturers' Research Association (Dunedin), etc.

2. Department and Council of Scientific and Industrial Research. This Department is organized in a method somewhat similar to that in U.K., but with an extended field. The annual expenditure is about £500,000. The organization is along the lines of the diagram at Fig. 1.

3. Royal Society of New Zealand (formerly the New Zealand Institute). This society, established formally by Act of Parliament in 1868, is the oldest scientific society. It has a governing council consisting of representatives of the various 'member bodies' in the larger towns, together with four government-nominated representatives (generally leading scientific men). It is the main organization for scientific lectures, discussions, etc., and publishes its quarterly transactions, consisting of papers mostly on biological and geological subjects. It receives a government grant of £750 per annum towards publications and has also numerous endowments. The society awards medals and various small grants for research and also elects Fellows each year so that the total number does not exceed forty at any time.

4. Cawthron Institute. This is a privately endowed scientific institution (£250,000) devoted mainly to scientific problems of agriculture and fruit. By arrangement with D.S.I.R. the main entomological work of the Dominion is conducted at the Institute, also certain aspects of soil and deficiency problems.

5. Department of Agriculture. Is responsible for the main agricultural advisory services of the Dominion. It carries out at Ruakura and Wallaceville the main researches in animal diseases and also, in close collaboration with D.S.I.R., in other agricultural problems.

The situation of the main research stations, etc., is indicated in attached map (Fig. 2).

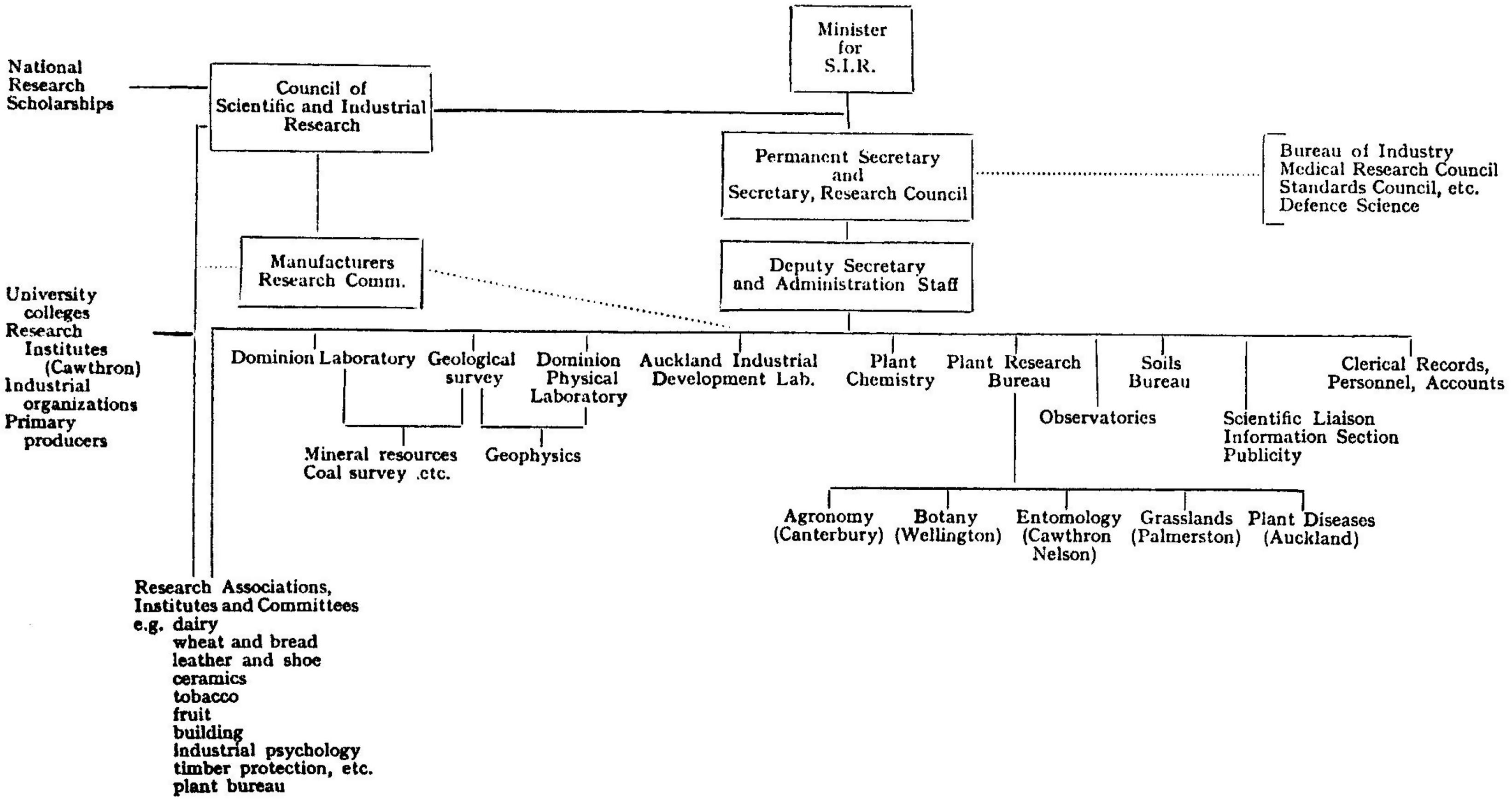

National Research Scholarships
Council of Scientific and Industrial Research
Minister for S.I.R.
Permanent Secretary and Secretary, Research Council
Bureau of Industry
Medical Research Council
Standards Council, etc.
Defence Science
Manufacturers Research Comm.
Deputy Secretary and Administration Staff
University colleges
Research Institutes (Cawthron)
Industrial organizations
Primary producers
Dominion Laboratory
Geological survey
Dominion Physical Laboratory
Auckland Industrial Development Lab.
Plant Chemistry
Plant Research Bureau
Soils Bureau
Clerical Records, Personnel, Accounts
Observatories
Scientific Liaison
Information Section
Publicity
Mineral resources
Coal survey .etc.
Geophysics
Agronomy (Canterbury)
Botany (Wellington)
Entomology (Cawthron Nelson)
Grasslands (Palmerston)
Plant Diseases (Auckland)
Research Associations, Institutes and Committees
e.g. dairy
wheat and bread
leather and shoe
ceramics
tobacco
fruit
building
industrial psychology
timber protection, etc.
plant bureau

FIG. 1

NEW ZEALAND
SHOWING
CENTRES of SCIENTIFIC RESEARCH

—References—

Scientific Industrial Research (D.S.I.R.)
University
Agricultural Dept.

SCALE

Grasslands Division, D.S.I.R.
Plant Chemistry Lab., D.S.I.R.
Massey Agricultural College
Soil Testing Station, D.S.I.R.
Dairy Research Institute, D.S.I.R.
Plant Research Station, D.S.I.R.
Tobacco Research Station, D.S.I.R.
Fruit Research Orchard, D.S.I.R.
Cawthron Institute (private)
Entomology Division, D.S.I.R.
Agronomy Division, D.S.I.R.
Lincoln Agricultural College
Rice Research Station, D.S.I.R.
Grasslands Division, D.S.I.R.
Fruit Research Station, D.S.I.R.
Otago University
Dominion Laboratory
Wallaceville Animal Research Station
Grasslands Division, D.S.I.R.
Canterbury University College
Dominion Laboratory
Magnetic Observatory
Defence Division, D.S.I.R.
Wool Research Institute
Botanical Section
Scientific & Industrial Research Head Office
Victoria University College
Plant Research Bureau, Head Office
Dominion Laboratory
Geological Survey
Soil Research Bureau
Dominion Physicist
Meteorological Office
Dominion Physical Laboratory
Botany Div., D.S.I.R.
Medical Entomology Division
Fruit Research Station
Fur Research Lab.
Leather Research Lab.
Ceramic Research Section

SCIENTIFIC ORGANIZATION IN PALESTINE

By Dr S. SAMBURSKY
(Palestine Board for Scientific and Industrial Research).

THE Palestine Board for Scientific and Industrial Research was set up in 1945, and is the outcome of the Scientific Advisory Committee of the Palestine War Supply Board which was founded during the war in order to organize the war effort of scientific institutions in Palestine. The Board for Scientific and Industrial Research is made up of two representatives of the Government, five representatives of the four major scientific institutions in Palestine, and two representatives of industry. The scientific institutions represented are : The Hebrew University of Jerusalem ; the Daniel Sieff Research Institute, Rehovoth ; the Agricultural Experimental Station of the Jewish Agency, Rehovoth ; and the Hebrew Technical College, Haifa. Members of the Palestine Standards Institution are represented on several of the Standing Advisory Committees of the Board.

The Board's first research projects have just been started, and they comprise engineering problems ; investigations in animal disease ; composition of local foodstuffs ; and fundamental research on bromine, which is one of the most important raw materials of Palestine. Long-term projects are being worked out on the other main product of Palestine, namely citrus products, where the co-operation of the research laboratories of the local citrus concentrate factories has been secured.

Special research committees are examining the problems of desalting of brackish water for irrigation purposes, and of a more rational utilization of Palestinian building stones.

Research programmes are being worked out, partly in co-operation with scientists of the Palestine Potash Ltd., for a systematic survey of minerals and rarer elements in Palestinian waters.

Particular attention is paid to fundamental research connected with essential raw materials of this country, and to biological problems arising out of the special climatic conditions prevailing here. A variety of research projects is being considered by the Agricultural Committee, including the important problem of the prevention of citrus wastage during transport and storage through the use of wrappers impregnated with diphenyl ; weed control ; industrial plant investigations ; soil survey ; nutritional problems ; poultry diseases and vole research.

THE ORGANIZATION OF SCIENTIFIC RESEARCH AND DEVELOPMENT IN SOUTH AFRICA

A Statement by the Scientific Adviser to the Prime Minister

I. INTRODUCTION

The general advisory body of the Government of the Union in regard to scientific research is the Council for Scientific and Industrial Research. The present distribution of responsibility for the carrying out of research is shown below :—

subject	body responsible	degree of responsibility
University research in science, medicine and engineering	C.S.I.R.	financial support
National research laboratories for physics, building, personnel selection and industrial psychology, chemistry	C.S.I.R.	full control
Industrial Research Association (leather and others to be formed)	C.S.I.R.	As in the case of the D.S.I.R., United Kingdom
Agriculture and veterinary	Dept. of Agriculture	full control
Forestry and forest products	Dept. of Forestry	full control
Geological Survey, metallurgical and minerals research	Dept. of Mines	full control
Fisheries	Dept. of Commerce	full control
Union Observatory museums	Dept. of Interior	full control
Trigonometrical Survey, Magnetic Observatory	Dept. of Lands	full control
Fuel Research Institute Deep Level Mining Research Institute South African Institute of Medical Research	autonomous bodies with Government subsidy	
Sugar Research Association Chamber of Mines Timber Research Laboratory	autonomous bodies	
Bernard Price Institute of Geophysical Research	University of the Witwatersrand	

II. THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

A diagram of the present organization of the Council and a brief report by the President on its activities and scope are attached at appendices 1 and 2.

III. AGRICULTURAL AND VETERINARY RESEARCH

A diagram giving details of the research organization of the Department of Agriculture is given at appendix 4, and some notes thereon in appendix 3.

IV. RESEARCH IN THE DEPARTMENTS OF FORESTRY, MINES, COMMERCE AND INDUSTRIES

The research activities of the Department of Forestry are summarized in appendix 5, and that of Mines in appendix 6, and the fisheries research of the Department of Commerce and Industries in appendix 7.

V. FUEL, DEEP LEVEL MINING, SUGAR, LEATHER AND TIMBER

Summaries of the activities of the institutions dealing with these subjects are given in appendix 8.

SOUTH AFRICAN COUNCIL FOR SCIENTIFIC & INDUSTRIAL RESEARCH

LEGEND
D ORGANIZATIONS UNDER C S I R CONTROL.
E FUTURE DEVELOPMENTS UNDER C S I R ORGANIZATIONS
E FUTURE OUTSIDE ORGANIZATIONS
LS OF C S I R CONTROL
CHANNELS

CABINET COMMITTEE

PRIME MINISTER

PRESIDENT AND COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

C S I R's ETC. OF OTHER COUNTRIES

GOVERNMENT DEPARTMENTS
FEDERATED CHAMBER OF INDUSTRIES
MINING INDUSTRY
UNIVERSITIES
TECHNICAL COLLEGES
ASSOCIATION OF CHAMBERS OF COMMERCE
SOUTH AFRICAN AGRICULTURAL UNION
SOUTH AFRICAN STANDARDS COUNCIL
SOCIAL & ECONOMIC PLANNING COUNCIL
RESEARCH GRANT BOARD SOCIAL & ECONOMIC
STATISTICAL COUNCIL
SOUTH AFRICAN MEDICAL ASSOCIATION
SCIENTIFIC & TECHNICAL SOCIETIES

C.S.I.R. LABORATORIES

- NATIONAL BUILDING RESEARCH LABORATORY
- NATIONAL PHYSICAL LABORATORY
- NATIONAL CHEMICAL RESEARCH LABORATORY
- NATIONAL HOUSING COMMISSION
- STANDARDS BUREAU AND LABORATORY
- ADVISORY COMMITTEES

C.S.I.R. BUREAUS & PROJECTS

- APPLIED AND INDUSTRIAL PSYCHOLOGY
- TELECOMMUNICATIONS
- NUTRITION AND ENVIRONMENTAL MEDICINE
- INDUSTRIAL HYGIENE
- NATIONAL COUNCIL OF NUTRITION

INDUSTRIAL RESEARCH

INDUSTRIAL RESEARCH ASSOCIATIONS

BOARDS OF CONTROL
- DEEP-LEVEL MINING
- LEATHER
- FISH PRODUCTS

INDUSTRIAL RESEARCH LABORATORIES
NOT C.S.I.R. BUT WITH C.S.I.R. REPRESENTED ON BOARDS OF CONTROL.

SPECIAL PROJECTS, TESTING & ADVICE

INDIVIDUAL FIRMS AND REGIONAL COMMITTEES

UNIVERSITY AND GENERAL RESEARCH

COMMITTEE ON RESEARCH GRANTS AND BURSARIES

RESEARCH GRANTS, STUDENTSHIPS, FELLOWSHIPS

SCIENTIFIC AND TECHNICAL INFORMATION

C S I R LIBRARY AND INFORMATION BUREAU

SCIENTIFIC LIAISON MISSION
- LONDON
- WASHINGTON
- MELBOURNE

DEVELOPMENT AND COORDINATION

COMMITTEES
- MEDICAL RESEARCH DEVELOPMENT
- AERONAUTICS
- EDUCATION IN SCIENCE
- TECHNICAL TRAINING

APPENDIX 2

THE SOUTH AFRICAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

(Summary of activities and scope 5 October 1945–2 February 1946)

1. General

The South African C.S.I.R. was set up in terms of the Scientfic Research Council Act, No. 33 of 1945, on 5 of October, 1945.

The Council consists of a full-time President and nine members. The President, who is directly appointed by the Government, is also the Chief Executive Officer.

The Council is a corporate body. It has charge of all matters affecting scientific and industrial research in the Union as may be assigned to it by the Prime Minister or which, with his approval, it may promote. It has also the duty of advising the Prime Minister on scientific and technological matters, while the Council's estimates are submitted annually to Parliament by the Prime Minister, who is Chairman of a Cabinet Committee appointed to control it.

2. Progress of the Council's Activities

As it is only four months old, the Council has not a great deal to report at the time of writing (2/2/46). Two of its laboratories, the National Building Research Institute and the Telecommunications Research Laboratory, are, however, already engaged on useful investigations.

(*a*) *National Building Research Institute*

Though not yet fully staffed, this Institute has made an early start, having been taken over from the Department of Commerce and Industries under whose wing it was inaugurated in 1945. It is at present undertaking field research on experimental types of housing in the Cape Peninsula for and in collaboration with the National Housing Commission, as well as general investigations of new building materials such as vermiculite. It is planned to develop a strong section on Soil Mechanics in this Institute.

The Institute has the advantage of an energetic Advisory Board representing all the professional and other building organizations of the country. The Chairman of the Board, acting as Director, has recently paid a visit to Britain and the United States to study building research organization.

(*b*) *Telecommunications Research Laboratory*

This laboratory, with a staff of five, is operating as a small unit housed by arrangement with the university in the Electrical Engineering Department of the University of the Witwatersrand. It is at present engaged on the development of automatic ionospheric sounding equipment and of equipment for the application of radar to the location of distant storm-clouds. The former investigation is of importance to the Post Office, the Broadcasting Corporation and other users of wireless, the latter to the meteorological services, power companies and mines.

(*c*) *National Physical Laboratory*

The Director and senior staff for this laboratory have been appointed and are planning their activities, particularly in relation to industry, prior to visiting Britain and the United States.

(*d*) *National Chemical Research Laboratory*

A survey of the requirements for this laboratory is being undertaken by an officer with industrial experience.

(*e*) *National Bureau for Personnel Research*

The Director and staff of this Bureau have been appointed, mainly from the staff of the Aptitude Tests Section of the South African Air Force, and will assume duty in March. Arrangements are in hand for close co-operation with industry and with the Departments of Education and Labour in the subject of aptitude testing and vocational guidance.

(*f*) *Medical research*

The Council has arranged with the National Nutrition Council for their research committee to act as the advisory committee on nutritional research to the C.S.I.R., who will supply the necessary funds.

A representative committee has been formed to report upon the general development of medical rsearch in South Africa.

(*g*) *Library, Information Bureau and Overseas Missions*

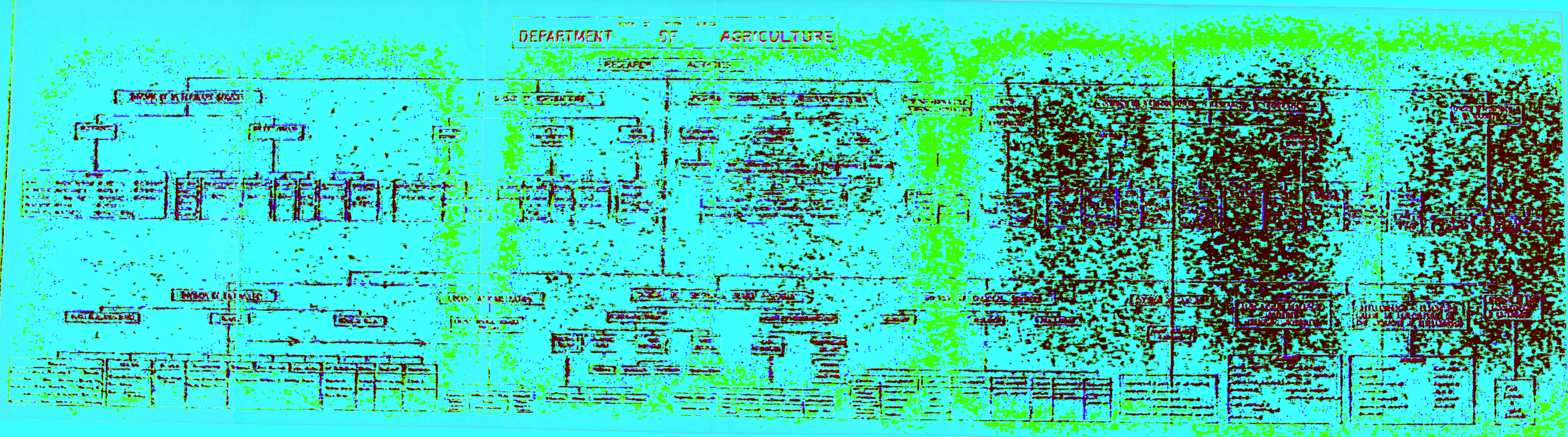
Arrangements are in hand for the staffing and establishment of the Council's library and information bureau. The C.S.I.R. already has a representative in South Africa House, London, with his own office staff. The Council will take over the work of the Union Government's Scientific Mission in Washington during July, 1946.

(*h*) *University research*

The Council's proposals in relation to support for university research have been well received by the universities. In brief, they are that the Council will receive from universities and university colleges their detailed proposals for block allocations for this purpose, under heads and under regulations laid down by the Council in relation to grants and bursaries. After proper scrutiny, the Council will make such allocations as it thinks fit, the allocations to be administered by the universities themselves and the results reported to the Council. The Council will not provide ordinary university equipment for research unless this is of a major character and of general value and remains its property.

(*i*) *Industrial research*

The Council has had close and frequent contact with the Federated Chamber of Industries, and its proposals in regard to the support and encourgement of industrial research have received the full approval of organized industry. It is actively engaged in the development of these proposals, both with regard to assisting individual industrialists in research matters and in the formation of industrial research associations.


DEPARTMENT OF AGRICULTURE

3. Accommodation

The main headquarters and national laboratories of the Council are situated in excellent temporary accommodation in some of the buildings erected in Pretoria for the munitions section of the Director-General of War Supplies.

APPENDIX 3

THE DEPARTMENT OF AGRICULTURE

The research activities of the Department of Agriculture are maintained by a number of Divisions and Sections. The Divisions actively engaged on research are :—

The Division of Veterinary Services,
The Division of Chemical Services,
The Division of Agricultural Education and Research,
The Division of Economics and Markets,
The Division of Dairying,
The Division of Soil and Veld Conservation,
The Division of Entomology,
The Division of Botany and Plant Pathology,
The Division of Horticulture,
The Stellenbosch-Elsenburg College of Agriculture,
The Agricultural Research Institute, Pretoria,
The Western Province Fruit Research Station,
The Low Temperature Research Laboratory,
The Dehydration and Cold Storage Laboratory,

The Locust Administration is a section which reports direct to the Secretary for Agriculture.

The Secretary and Under-Secretary and the Chiefs of most divisions are stationed at Pretoria. The exceptions are the following, whose headquarters are at the places indicated : The Stellenbosch-Elsenburg School of Agriculture, Stellenbosch ; The Western Province Fruit Research Station, Groot Drakenstein, Stellenbosch ; The Low Temperature Research Laboratory, Cape Town ; and the Dehydration and Cold Storage Laboratory, Cape Town.

The research activities of the various divisions cover the investigation of agricultural problems in all the various climatic regions of the Union, and are outlined in the accompanying diagram (appendix 4), facing page 144.

APPENDIX 5

DEPARTMENT OF FORESTRY

Research undertaken by this department may be divided into the following three categories :—

1. Silvicultural Research

The department maintains five centres of silvicultural research, viz. Northern Transvaal, Eastern Transvaal, Natal, Cape Midlands and Western Province. This field of investigation deals with the raising and tending of forest crops and includes the study of soil preparation, formation methods, fertilizing, growing space, mixtures, cultivation, weeding, thinning, pruning, yields, underplanting, regeneration, trials of new species, forest genetics and protection (both entomological and pathological).

Specific laboratories are not maintained for this work and specialized problems in pathology, mycology, chemistry and entomology are dealt with in collaboration with the appropriate Divisions of the Department of Agriculture.

Seven professional officers and an equal number of foresters and technical assistants devote their full time to this branch of research. Owing to the shortage of trained staff, several of these posts are now vacant.

2. Forest Influences Research

The department maintains two forest influences research stations, one at Jonkershoek (Stellenbosch) and the other on the Drakensberg. At these stations the catchments of numerous perennial streams are treated in various ways to measure the effect of treatment on run-off, erosion, seepage and streamflow. While it is known that the afforestation of a catchment tends to regulate streamflow, its quantitative effect upon the rate of flow during critically dry periods has yet to be determined. These are long-range projects and it is unlikely that conclusive results will be obtained in less than half a century.

Each station maintains or will maintain an appropriately equipped laboratory and a full range of self-recording instruments to measure meteorological factors and streamflow. Three professional officers and two technical assistants are currently employed in this field of research and additional staff will be made available as soon as possible.

3. Forest Products Research

The Department maintains a Forest Products Research Institute at Pretoria West whose main functions are the investigation of all problems connected with the conversion, treatment and utilization of indigenous and locally-grown exotic timbers.

At the time the Institute was established, little was known about the properties of local timbers and even less about the most suitable methods of handling them. To-day much of the prejudice which existed against the local product has been overcome. The properties and uses of over 200 species have been described and the practical value of all the more important ones clearly demonstrated on a large scale.

The Institute maintains a reasonably complete range of experimental kilns, seasoning plants and machinery for sawing, planing, wood-testing and pulp and paper making.

The staff of the Institute at present comprises five professional officers and four technical assistants together with a large number of daily-paid employees.

APPENDIX 6

DEPARTMENT OF MINES

The Department of Mines contains two technical divisions :—

A. Government Mining Engineer's Division.
B. Geological Survey Division.

It also carries on its vote funds for the upkeep of the Government Metallurgical Laboratory which is governed by a Committee of Control composed of three members of the Department and three nominees representing the University of the Witwatersrand. The Government Mining Engineer is chairman of this Committee.

A. Government Mining Engineer's Division

(i) Government Mechanical Laboratory. 2 professional officers. Carries out tests on the mechanical properties of materials used by mines, the majority of the tests being on the tension of wire winding ropes. Has apparatus for testing tension, torsion, fatigue, crushing strength, bending properties, hardness, and hydraulic pressures.

(ii) Miners' Phthisis Prevention Committee. 5 professional officers. Investigates, with the aid of technical assistants, all non-medical factors affecting the incidence of miners' phthisis in mines.

(iii) Miners' Phthisis Medical Bureau. 12 medical examiners, 1 radiologist, 1 electrotechnician-radiographer, plus 3 medical officers, constituting a Board of Appeal. Carries out periodic examinations of all miners in 'scheduled' mines and co-operates with the South African Institute for Medical Research in the medical study of miners' phthisis.

B. Geological Survey Division

Director and assistant director, 65 professional officers, 21 technical assistants (not graduates). Undertakes geological and mineralogical investigations in the Union and South-West Africa. It is responsible for :

(*a*) geological mapping and the production of geological maps and explanations thereto ;
(*b*) investigation into the country's resources of minerals, and the publication of these results in the form of mineral memoirs, bulletins, etc. ;
(*c*) investigation into underground water supplies ;
(*d*) investigation into the field uses and application of geophysical instruments, and geophysical surveys ;
(*e*) investigation of problems in civil engineering which involve geological principles ;
(*f*) mineralogical and petrological research ;
(*g*) palaeontological research ;
(*h*) the organization and maintenance of departmental geological museums.

GOVERNMENT METALLURGICAL LABORATORY

Part-time director, 10 professional officers. The functions of this organization are :

(*a*) to study and investigate mineral resources, except fuel, from the standpoint of their utilization and to encourage their development by research and experiment ;
(*b*) to conduct metallurgical research and investigations of scientific or industrial importance ;
(*c*) to conduct the testing of minerals and metallurgical products, and to collaborate in the determination of the standard specifications of these products ;
(*d*) to afford facilities for research scholars to conduct researches or otherwise aid in the functions referred to above.

APPENDIX 7

DEPARTMENT OF COMMERCE AND INDUSTRIES

DIVISION OF FISHERIES

The research programmes of the Division of Fisheries may be tabulated as follows :—

(1) Survey of fishing grounds as to location of new grounds and fluctuations of supplies on known grounds by r.s. ' Africana ' and p.b. ' Impala,' specially constructed survey vessels.

(2) Research in fisheries :—

(*a*) hydrobiology—chemistry and physics of the sea, and hydrodynamics—current systems and oceanography ;
(*b*) fluctuations of supplies—problems of over-fishing ;
(*c*) surveys of new grounds for intensity of supplies on basis of catches per unit of effort ;
(*d*) fisheries technology—canning, smoking, drying and salting ;
(*e*) fish body and liver oils (in co-operation with the department of chemistry, University of Cape Town) ;
(*f*) fish meals and fertilizers (in co-operation with the department of chemistry, University of Cape Town) ;
(*g*) other by-products ;
(*h*) dietetics.

(3) Development of fishing harbours,
(4) Statistics of catches,
(5) Whaling,
(6) Seaweed research—production of agar agar, iodine, etc.,
(7) Development of inshore fisheries,
(8) Restocking of depleted grounds by artificial cultivation,
(9) Conservation and legislation,
(10) Studies of modern fishing gear.

Survey vessels

Tenders close on 28 February for the construction of a new survey vessel to replace the r.s. 'Africana.' The new ship will be 213 feet long with a tonnage of 1500 tons and a speed of 14 knots.

The most modern designs and apparatus have been embodied in this ship so as to be assured of the possession of an all-purpose vessel. Her operational range will be 8000 miles with a sea-endurance of 24 days. She will be fitted with radar, wireless, two echo-sounding sets (0–360 fathoms and 0–3000 fathoms) and a large laboratory with an oil reducing plant and refrigeration.

The other vessel, p.b. 'Impala' is a diesel boat, 55 feet in length, 45 tons, specially constructed for patrolling and surveying the crawfish grounds. She also carries out surveys into inshore fisheries.

Staff

The professional staff consists of the director of fisheries, who is also the government marine biologist, three chemists, six biologists and a harbour engineer.

APPENDIX 8

FUEL RESEARCH INSTITUTE

The Fuel Research Institute was established under Act No 36 of 1930 as a corporate body with terms of reference :—

(*a*) to study and investigate the fuel resources of the Union ;
(*b*) to undertake scientific and technical research on all matters relating to fuels in general and to fuel by-products ;
(*c*) to grade coals for export or bunkering ;
(*d*) to undertake any other matters referred to it by the Minister in consultation with the Board.

The finances of the Institute are derived from a levy of 1d. per ton on coal sold during the preceding calendar year by collieries producing not less than 25,000 tons per annum, and from a *pro rata* parliamentary appropriation. The Institute is also authorized to charge fees for services rendered other than the grading of coal for export or bunkering.

The Institute employs 12 research officers, 20 technical assistants (graduates or under-graduates employed on routine analysis) and 2 workshop mechanics.

THE LEATHER INDUSTRIES RESEARCH INSTITUTE

This Institute evolved from the Tanning, Hides and Skins Department at Rhodes University College, Grahamstown, and its researches cover all phases of the leather industries from raw material to finished footwear.

It receives about £15,000 per annum in the form of grants from industry and certain government departments, together with a *pro rata* subsidy from the Government. It will shortly come under the Industrial Research Association scheme of the C.S.I.R.

The Research Institute is organized into the following sections : chemistry, biochemistry and entomology, industrial economics, personnel research and engineering, employing in all some 15 research officers, 2 technical assistants and 5 student assistants. There is also provision for research scholarships which can be held at the Institute.

SOUTH AFRICAN SUGAR ASSOCIATION

The Experiment Station, Mount Edgecombe, Natal, was established in 1925. The chemical laboratories were built in 1927, and the botanical and entomological laboratories at a later date. There are some 80 acres of land under field experiments.

It is financed solely by the S.A. Sugar Association, who contribute £13,000 per annum towards its maintenance. The capital costs were originally defrayed by a loan of £10,000 from the Government, which has since been repaid in full.

The experiment station undertakes problems such as the study of varieties of sugar cane new to South Africa, soil surveys, studies of the maintenance and restoration of soil fertility by means other than the supply of commercial fertilizers, agricultural experiments with fertilizers, the diseases and insect pests of sugar cane, and the production of cellulose from sugar cane bagasse. In recent years the station has concentrated almost entirely on agricultural and botanical research work.

There are some 13 professional officers on the staff, and 1 laboratory assistant.

THE CHAMBER OF MINES

TIMBER RESEARCH LABORATORY

The chief purpose of this laboratory is to investigate the causes of decay of mine timbers and to develop suitable preservative treatments.

The technical staff, in addition to the director, consists at present of 2 mycologists, 3 chemists, and 1 technical assistant.

THE SOUTH AFRICAN INSTITUTE FOR MEDICAL RESEARCH

The S.A.I.M.R. was established in 1912 by agreement between the Union Government and the Witwatersrand Native Labour Association (acting on behalf of the mining industry of the Transvaal) for the purpose of :—

(1) carrying out research with a view to the prevention and treatment of human disease ; and
(2) providing routine medical laboratory services and the preparation of materials such as vaccines and sera for the prevention and treatment of disease.

The reasearch work which has been carried out by the Institute since its establishment may be classified into :—

(1) Technological research concerned with the improvement of routine procedures for diagnosis and the preparation of vaccines, sera and other therapeutic substances such as vitamins and hormones.

(2) Investigation of local public health and industrial hygiene problems.
(3) Unfettered research where the worker is not required to study any set problem but is guided by his own talents and inspiration—referred to variously as 'true,' 'scientific' or 'fundamental' research.

It is not always easy to adhere to this classification. Thus research on rickettsiae, commenced for the reason only that one of our officers evinced a special interest in these organisms, in time supplied valuable information regarding the serious public health problem of typhus endemicity in the Native Reserves and finally resulted in the production of a satisfactory vaccine of which over two million immunizing doses were supplied to Russia during the war. Nevertheless, for purposes of administration it is a convenient classification. The surplus of revenue over expenditure on routine services can correctly be utilized for the improvement of those services. Other research which cannot ordinarily be applied to revenue producing services must be supported by grants from the State or other sources.

Technological research

Since the Institute is a non-profit organization the excess of revenue over expenditure must be spent on improvement of the services of the Institute. In the past this has made possible considerable extensions to buildings and plant and has been consistently used to meet the deficit on the Research Division of the Institute. During the war years the surplus was considerable, so that extensions were made to meet the ever-increasing war demands. The amount which will normally be available for technological research may be assumed to be about £5000 per annum, though this will vary according to the demand for routine services, and it would be appropriate that the amount of technological research should vary accordingly allowing for an inevitable lag in the appointment of staff and the purchase of equipment.

Research into State and industrial health problems

The Institute receives annual grants of £7500 each from the Union Health Department and the Witwatersrand Native Labour Association. This is used for the purchase of equipment and the payment of salaries of staff engaged in research into health problems of interest to the State and the mining industry. Where officers devote part of their time to routine duties the costs are apportioned accordingly. The studies of special public health interest which have extended over many years include plague, malaria, bilharziasis, leprosy, tuberculosis, nutrition, etc. Of more particular mining interest were the studies of pneumonia, silicosis and dietetics.

THE DEEP LEVEL MINING RESEARCH INSTITUTE

Steps are being taken to establish a Deep Level Mining Research Institute to investigate methods of mining which will extend the limits (in depth) to which mining operations can be profitably conducted, and

methods of safeguarding the health of persons engaged on such ultra deep level mining operations.

The finances of the Institute will be provided by contributions from persons or bodies corporate engaged in mining in the Union, and by a parliamentary appropriation administered through the Department of Mines.

ORGANIZATION OF SCIENTIFIC ACTIVITIES IN SOUTHERN RHODESIA

Since the granting of responsible government to Southern Rhodesia in 1923 there have been considerable expansions in the scientific organizations set up under the various Government Departments, and the extent and scope of these organizations will be given in some detail later in this report. In addition, during the past twelve years there has been a further development by the constitution of public utility boards or commissions under quasi-government control to deal with supplies of essential services such as electric power, or to undertake some specific line of research work such as tobacco research.

Outside of these government or quasi-government bodies there is in existence a *Rhodesia Scientific Association* which was founded as long ago as 1899 with the object of furthering interest in scientific work in the Colony and giving scientific and professional workers an opportunity of meeting at regular intervals for the presentation of papers and discussion of matters of mutual interest.

The Association is financed by subscriptions of members and a government grant of £200 per annum and donations for special purposes. The Proceedings of the Association are published annually and widely distributed. The present membership of the Association is 180. We have been honoured by visits from the British Association in 1905 and 1929, and from the South African Association for Advancement of Science in 1911, 1920 and 1927. Further details of the Association are contained in Appendix I.

Specific professional organizations in existence are the *British Medical Association* (organized in two branches and having within its membership over 90 per cent of the medical practitioners in the Colony), the *Rhodesian Society of Architects*, and the *Rhodesian Institute of Land Surveyors*. All three of these professions are protected by legislation to prevent unqualified persons from practising.

A *Rhodesian Society of Engineers* was formed in 1945 and includes the civil, electrical, mechanical, mining and structural branches of the profession. One of the objects of the Society is to promote legislation to prevent unqualified persons from practising the profession. The professional officers in Government employ formed a *Professional and Technical Officers Association* in 1928 with the object of ensuring a high standard of qualifications for professional entrants to the Service, and improving the grades and rates of pay offered. This association, which is affiliated to the *Southern Rhodesia Public Services' Association*, has performed a valuable service in this connexion.

As regards *scientific education* there are at present no universities established in the Colony, although certain proposals in this connexion are at present under consideration and one generous benefactor has contributed £20,000 for this purpose. The general consensus of opinion, however, is that it would be inadvisable, owing to the limited European population, to establish

a university in the Colony and it would be preferable for the Government to extend the present policy of grants or bursaries to promising students to enable them to undertake university training in the Union of South Africa or overseas. Even under present circumstances young Rhodesians are well served by the grants available from the Rhodes and Beit Trustees and Government bursaries.

It seems probable that certain proposals for the establishment of a research institute, instead of a university, will be those ultimately adopted. The *Central African Council*, see Appendix II, which is comprised of Government representatives from Southern Rhodesia, Northern Rhodesia and Nyasaland, has recently appointed a special committee on joint research for the three territories. The Committee's terms of reference are that steps should be taken to co-ordinate research in the three territories and that a special committee of two members from each territory, with power to co-opt additional members, should be appointed to explore the possibilities, and in particular, the appointment of a joint director of research. Standing Committees on trypanosomiasis, conservation and natural resources, and medicine, have been appointed. (See Appendices II and III).

The present tentative proposals are that the research institute should be financed by grants from the three governments and under competent directors should confine itself to research into local problems connected with public health, nutritional standards for natives, and agriculture.

The workers in the institute would be post-graduate students who, under a system of government bursaries, would undertake research on specific problems as approved by the director. It is also suggested that there should be an Empire central research organization which would be a clearing house for scientific information received from all over the Empire.

In 1924, in collaboration with the Empire Cotton Growing Corporation, a cotton research station was established at Gatooma, to develop a type of cotton suited to the soil and climatic conditions of the Colony and to study as far as possible the incidence and intensity of the various insect pests and plant diseases. Later, in 1936, a *Cotton Research and Industry Board* was established by Parliament to supervise all cotton research and to assist the development of a cotton industry. The powers of the Board were increased in 1942. A spinning mill has been built which utilizes both Rhodesian and other African cottons. The yarn produced is used by local firms for the manufacture of cotton blankets, interlock and other forms of under- and outer-wear. An absorbent wool is also produced. A weaving factory is in course of erection close to Gatooma and it is anticipated that it will be turning out woven fabrics such as calicoes, sheetings, drills, shirtings, etc., by the end of the year.

The *Tobacco Research Board* consisting of representatives from the industry and the Agricultural Department has full executive powers for the appointment of staff to undertake research in the growing and curing of Virginia and Turkish types of tobacco. It is financed by revenue earned by sale of tobacco grown on the station, donations from the industry and by annual Government grants. Only one main research station has been established to date at Trelawney where valuable work has been carried out on the

propagation of improved strains of Virginia and Turkish tobacco suitable for local conditions, and increased yields per acre by proper fertilizer treatment.

Although not a research board, the *Natural Resources Board* (see Appendix III) performs a most important scientific function in conducting propaganda and educating the public to a realization of the necessity and the manner whereby our natural resources can be conserved and properly utilized. This board has very wide powers under an Act for exercising control over the operations of landowners to ensure proper methods of land usage.

Government subsidies are available for the growing of crops such as maize and wheat under defined good farming conditions in that the land under cultivation has been adequately protected and has been properly green-manured or composted. The Colony can rightfully claim that it is well to the fore in the adoption of soil conservation measures and the Government refunds one third of the cost of properly constructed soil conservation works on privately owned land.

Conservation officers attached to the Irrigation Department set out the work, and Government-owned tractor units are available to carry out the construction. To date some 25,000 miles of contour ridges have been constructed for the protection of 600,000 acres of land.

Government grants and loans are available for the training of ex-servicemen as conservation officers and at present fifteen are undergoing a three years' course of training at Witwatersrand University. The Natural Resources Board was also instrumental in establishing a Pasture Research Branch under the Department of Agriculture to undertake research into proper methods of pasture management and the improvement of our natural pastures. Two main stations have been established and it is intended, within the next two years, to establish six sub-stations in various typical areas.

A *Trypanosomiasis Committee* was formed in 1934 with the Prime Minister, the Hon. Sir G. Martin Huggins, K.C.M.G., C.H., F.R.C.S., M.P., as President. The members of the Committee represented all the various sciences concerned in the study of trypanosomiasis, including the interests of the indigenous population, and their terms of reference were to consider all questions relating to the trypanosomiasis of man and animals in Southern Rhodesia, to submit reports, and to make representations to Government. A Trypanosomiasis Bureau for the collection, collation and distribution of literature was formed at the same time. The committee has maintained close relations with neighbouring territories and recently a co-ordinating committee has been set up under the Central African Council.

Trypanosomiasis carried by the tsetse flies, of which three species occur in Southern Rhodesia, is one of the main problems requiring a solution before the tsetse infested areas can be economically developed. Approximately 6,000 square miles of land has been reclaimed and a further 4,000 square miles partially reclaimed; 16,000 square miles of the Colony remains infested. The Colony is threatened with invasion at various points along the border by tsetse advancing from Portuguese East Africa.

The *Electricity Supply Commission* (see Appendix IV) was founded as a public utility company by Act of Parliament in 1936. The Commission supplies electricity to local authorities for distribution in urban areas and

distributes direct to farms and mines and other industrial undertakings in the country. Six generating stations have been opened and the plant on order and installed totals 158,300 kW. Electricity is generated by coal fired steam plants. Wankie coal of 13,600 B.T.U. gross calorific value is used, costs range from 15/8 at Bulawayo to 26/4 at Umtali per 2,000 lb ton.

Transmission voltages are 33, 66 and 88 kV and in rural distribution 11 kV. A total of 1,600 route miles in these categories have been installed. The system is being rapidly extended. Owing to the seasonal nature of the rivers water power has not been used but since 1941 hydrographic and engineering surveys of the Zambesi river at Kariba gorge have been done. This source of power would be 150 miles from the present nearest developed area.

The *Industrial Development Commission* (see Appendices IV and V) has been set up to advise the Government on all matters relating to the establishment, development, improvement and efficient conduct of industrial undertakings in the Colony. Among its principal objects are the co-ordination of industry on a balanced plane by promoting new industries ; advising on the acquisition or establishment of industries by statutory bodies ; advising on economic policy including tariffs, subsidies, quotas and marketing of products ; to promote or assist in schemes for expansion, modernization and greater efficiency, and to prosecute research into projects approved and financed by Parliament.

Liaison is maintained with the newly established Iron and Steel Corporation through the Chairman, who also holds that office in the latter organization.

With regard to industrial research, it is considered that in such a small country as Southern Rhodesia the establishment of a research institute to cover the field completely is impracticable, but what is desirable is a central scientific organization on the lines of the Imperial Agricultural Bureaux to form a common pool of scientific information on which all contributors could draw.

It is clear that none of the smaller Colonies can afford a complete research and scientific organization, but if a branch of the central organization were set up in each country to co-ordinate all the scientific work done both by Departments and by its own institute, each communicating direct with the central office, the demand could be met at a cost which all could afford, and which, in fact, could be graded in accordance with the ability to pay without limiting the extent of the service.

The *Sugar Industry Board* was established in 1945 for the purpose of undertaking a large scale experiment in the growing of sugar under irrigation on the Triangle sugar estates. If this experiment is successful it will prove the possibility of sugar growing being undertaken on an extensive scale in our low veld areas.

The *Mines Department* and *Geological Survey* Departments are administered by a Minister of Mines and the organization is set out in Appendix V.

All mining research is conducted by the Government with the exception of one experimental flotation plant at the Gaika mine. The Geological Survey produce maps and bulletins concerning all the more important fields. The Metallurgical Department provides an advisory service in the methods of treatment of ore. In 1938 a roasting plant was established to

treat the refractory gold ore concentrates, especially the arsenical and antimonial ores and slags.

Geophysical surveying has been carried out for various firms and the Government by private practitioners and all types of apparatus have been given a trial at different times in the Colony. Magnetometer, torsion balance, explosion methods and all resistivity methods have been used. Two Megger units are used by the Irrigation Department before drilling for water.

The Department in all its branches provides a free advisory, assay and inspection service primarily for the assistance of the ' small worker ' who produced 43 per cent of the annual gold output in 1945. A ' small worker ' mine is one which produces less than 5,000 oz. of gold per annum.

In 1939 a Silicosis Bureau was established and the Government administers an interim compensation scheme for silicosis and asbestosis.

Communications have developed much in recent years. In a country of great distances and small population the provision of adequate and efficient transport services is of vital importance. This has been recognized by the Government, and the *Roads Department* has developed a system of all-weather roads which make all but the most outlying districts readily accessible all the year through. This system is based on the use of tarmacadam ' strips,' spaced at standard motor car track distance, laid on gravelled roads, and the building of low level bridges to span the many small streams and rivers which at one time were crossed by ' drifts.' The whole system is co-ordinated with the railways, and in many districts road motor services of heavy lorries and trailers are operated by the railways, as well as by private companies. Many of the low level bridges have been built by the Beit Railway Trust, which has also provided the three great high level bridges namely the Birchenough, the Otto Beit and Alfred Beit, over the Sabi, Zambesi and Limpopo rivers respectively, thus providing inter territorial links directly or indirectly with neighbouring countries.

The Beit Railway Trust founded by the late Sir Alfred Beit has given large sums towards the furtherance of education, the improvement of transport and the assistance of research in the two Rhodesias.

Under the aegis of the Central African Council the three territories have agreed to establish by Act of Parliament an air service for the development of internal communications and feeder services.

The construction of an international airport capable of taking the largest land planes is under consideration.

The *Education Department* organizes science teaching in Southern Rhodesian schools as under. (See Appendix VI.)

(*a*) All academic high schools in Southern Rhodesia are engaged in science teaching on lines laid down by the Cambridge Syndicate for the School and Higher Certificates issued by that body.

(*b*) Modern high schools and the ' modern ' courses in bilateral high schools provide courses in general science suited to the particular needs of the area in which the school is situated.

(*c*) In the academic high schools the following trends are noticeable :

(i) the spread of general science in place of physics or chemistry in the curriculum of the Cambridge School

Certificate classes—three of the ten high schools have so far adopted general science ;

(ii) the complete disappearance of botany (as a separate science subject for examination) from the curriculum of girls' schools and its replacement by biology.

A *National Museum* has been established at Bulawayo.

The foundation of a *National Herbarium and Botanic Garden* has been approved.

The general organization of the *Public Health Department* is shown in Appendix VII. The Central Government's Public Health Department conducts the only organized research in the medical sciences.

Until 1939 there was no resident research organization ; before that date the Government encouraged research by the provision of laboratory accommodation and financial aid for a series of research fellows from the London School of Tropical Hygiene and Medicine. Between 1922 and 1936 a series of workers investigated the epidemiology, diagnosis, biochemistry and treatment of blackwater fever, studied the vectors of malaria and differentiated the sub-varieties of *Anopheles funestus* and studied the molluscan intermediate hosts of human schistosomiasis.

The Colony, founded in 1890, had no organized routine laboratories until 1902 when as the result of an epidemic of rabies a Pasteur Institute was founded to serve South Central Africa. In 1909 the first clinical laboratories were started at Bulawayo and Salisbury. These laboratories have increased in size and increased their scope, and employ three doctors (two directors and a pathologist) and a number of assistants. Branch laboratories have been established at two other centres. At Salisbury training of African microscopists is carried on. In 1929 an analysts' laboratory for medico-legal investigations and the control of drugs and food-stuffs was established. In 1945, 130,000 laboratory examinations were performed, the majority being of a clinical nature.

In 1938 with the financial aid of the State Lottery Trustees a scheme was prepared for a resident research nucleus to which would be attached visiting workers from overseas studying any of the medical, public health or nutritional problems for the study of which this country was well suited. A research laboratory was built and work on schistosomiasis begun. The outbreak of war brought all work to a standstill save for one worker studying the ecology of the snail, intermediate host of this disease. In 1945 work on other aspects of the disease was taken up again and studies on ' fast treatment ' with antimony salts and ' fast diagnosis ' with a cercarial antigen carried out and taken to the stage of large scale field trials.

Under the aegis of the Central African Council, Southern Rhodesia will provide mental hospital facilities for the three territories and undertake the training of African radiographers.

Broadcasting and Telecommunication (see Appendix VIII) problems peculiar to Southern Rhodesia frequently present themselves, and the following may be of interest.

Because of the difficulty, due to excessive noise levels, of providing broadcast coverage at distances beyond the range of low power medium

wave transmitters but too near to be served by short wave transmitters, the possibility of utilizing the rural party telephone network, which extends over the whole of the Colony, as a distribution medium is being investigated.

To avoid the disadvantages attendant upon the use of special types of radio receivers transmission takes place on a frequency in the medium wave broadcast range by means of suitable coupling to the telephone network without interference to normal telephone conversation. Commercial broadcast receivers are used.

Measurements are now being made in order to ascertain the typical attenuation characteristics of the various types of line, and at the same time more efficient coupling systems are being developed.

An experimental system has been in use for some time and the results so far obtained are consistently good up to forty miles.

It is believed that Southern Rhodesia experiences lightning as severe as anywhere in the world, and the consequent interruption to telecommunication services has in the past been responsible for extensive damage to apparatus and delay to traffic.

The provision of efficient protection of apparatus and equipment has been a problem which has exercised the minds of our engineers for many years, and they have been rewarded as a result of their research.

By the application of the simple ' filter ' theory combined with the use of gas type dischargers, a system of protection of apparatus and equipment has been evolved with marked success, resulting in economy in maintenance and increased efficiency of service. Research is still proceeding in this direction.

Within the *Department of Native Affairs* there are sub-departments dealing with native education, native agriculture and land development, and engineering. One government school and two mission aided schools give secondary education. Agricultural training is given at two government schools and at several mission schools.

Soil erosion in the native areas is being energetically tackled and the land demarcated into pastoral and arable land. Water conservation schemes are being constructed and additional water supplies by means of wells and boreholes are being provided. De-stocking of the over-stocked native areas is in progress to prevent soil erosion. Better methods of agriculture, including crop rotation, green manuring and the application of farm manure to the land is being demonstrated throughout the native areas by trained native agriculturists. The poor native livestock are being improved by selective breeding and the introduction of better bulls. Some extensive irrigation schemes have been developed principally in the Sabi valley.

Health clinics are maintained in most of the native areas with native trained medical orderlies in charge. Native crafts and industries are being developed.

Agriculture forms the basis of the economic life of the Colony. A *Department of Agriculture* was constituted in 1903 embracing the veterinary services. The growth of the Department has been continuous, checked only by outside circumstances, the aim being to provide for the present farmers, to prepare for the time when the numbers must be much greater,

and to facilitate settlement by supplying the settler with information as to the possibilities of the country and the best means of making a living by farming. Under this policy the activities of the Department have multiplied many fold since its inception. The organization of the Department at the present time is as shown in Appendix IX. This includes natural resources, animal husbandry, poultry, industry, agriculture, horticulture, plant pathology and botany, tobacco, forestry, chemistry (including soil surveys), entomology (including tsetse fly research and reclamation and anti-locust measures), pasture research and assistance to farmers.

Separate departments within the Division include lands, Surveyor General, veterinary, veterinary research and irrigation, including meteorology.

An Agricultural Experiment Station is situated at Salisbury, a sub-tropical station at Umtali and pasture research stations at Marandellas and Matopos. Demonstration farms are to be established at suitable centres.

A divisional Conservation Committee has been formed within the past year on which are represented heads of departments and sub-departments actively concerned with the conservation of natural resources. They meet monthly to discuss joint problems and make recommendations to the Secretary. Heads of other sub-departments are invited to attend when specific problems affecting them are on the agenda. The committee is purely advisory and has no executive powers.

A Plant Regulatory Board within the Department of Agriculture acts as an advisory body in the implementation of the Plant Protection Act. Its main duties are to prevent the importation of plant diseases and pests, to control, where necessary, the dissemination of serious pests and diseases within the Colony, and to maintain liaison with neighbouring states on the Plant Interchange Schedule in matters of legislation or other phases of pest and disease control.

The *Irrigation Department*, which comes under the control of the Minister of Agriculture and Lands, consists of the following five sections, viz., irrigation and water supplies, hydrographic, soil conservation, boring and meteorology.

The *Irrigation and Water Supplies Branch* undertakes advisory work to farmers on irrigation and water conservation schemes, the investigation and supervision of construction of Government major irrigation and water conservation schemes, the construction of water conservation works in the native areas and supervision of water supply schemes to serve Government Institutes and out-stations.

The *Hydrographic Branch* undertakes the investigation of run-off from various typical catchments and gaugings of all the important rivers and streams—this latter function is a very important one as under the Water Act all public water is vested in the State and applications have to be made by landowners for grants for beneficial use.

The *Soil Conservation Branch* undertakes the setting out of protection works, contour ridges, storm drains, etc., and government tractor units are available for the construction of these works on payment of a defined scale of charges.

The *Boring Branch* undertakes the development of underground water

supplies by means of Government boring plants in the native areas, Crown lands and on private farms.

Prior to boring the sites are selected by geophysical survey—the electrical resistivity method being employed—a considerable degree of success has been obtained by this method and enables rebates of 75 per cent of the boring charges at approved sites if a supply is not developed.

The *Meteorology Branch* undertakes the compilation of rainfall and climatological data for both Southern and Northern Rhodesia and issues daily and short period forecasts of weather conditions and a seasonal forecast of probable rainfall.

During the war period the branch was taken over by the Air Force, and owing to its intimate connexion with forecasts for aviation purposes it is probable that in the near future it will become a branch under the Department of Civil Aviation.

Veterinary Services. This is taken care of by two separate Departments—*Veterinary* and *Veterinary Research.* The former is concerned with the general administration of regulations for the prevention and control of scheduled infectious diseases and assisting and advising stock-owners in maintaining their animals in a healthy and thrifty condition. Qualified veterinarians are stationed, at present, in five different centres and these have under them laymen trained as cattle inspectors. Cattle inspectors are also stationed at all the more important stock-raising centres throughout the Colony. The Veterinary Department is also responsible for the inspection of meat and animal products designed for export and for local consumption.

The Veterinary Research Department employs only two veterinarians and three lay laboratory officers and is mainly engaged on the laboratory diagnosis of disease and the preparation of vaccines or remedies for disease control. Research is therefore extremely limited and can only be pursued spasmodically when pressure from routine work permits, or when outbreaks of disease render experimental undertakings urgently essential. This Department is also engaged in collecting the latest scientific information concerning animal health generally, disseminating much information to the stock-owners.

Southern Rhodesia is free from some of the most serious diseases, viz. rindepest, pleuropneumonia, rabies, glanders, haemorrhagic septicaemia, bacillary white diarrhoea, newcastle disease, and infectious laryngotracheitis. The tick transmissible diseases are the commonest destructive diseases encountered, e.g. piroplasmosis, anaplasmosis, heart water, east coast fever and other forms of theileriosis, but quarter evil and anthrax also take their toll. Trypanosomiasis is of importance in the tsetse fly areas, foot and mouth disease has occurred intermittently since 1931 but rarely assumes virulence. Tuberculosis is present but its effects are only rarely apparent. Contagious abortion is very widespread and is responsible for serious though not readily apparent losses to the livestock industry. Lumpy skin disease has recently made its appearance. Parasitosis, both internal and external, play their part as also do poisoning, both of vegetable and mineral origin—arsenic especially accounting for many deaths, on account of its ubiquitous distribution for tick control. Mastitis also occurs and with more intensive systems of dairying will assume importance. A form of infectious sterility known as ' epi-vag ' and characterized by indurative epididymitis

was first encountered in 1944, but so far has remained comparatively localized.

The *Department of the Surveyor General* is responsible for the geodetic, topographical and boundary surveys of the Colony, also the production of maps, cadastral farm surveys and diagrams issued with Deeds of Grant and Transfer which have to be registered with the Registrar of Deeds.

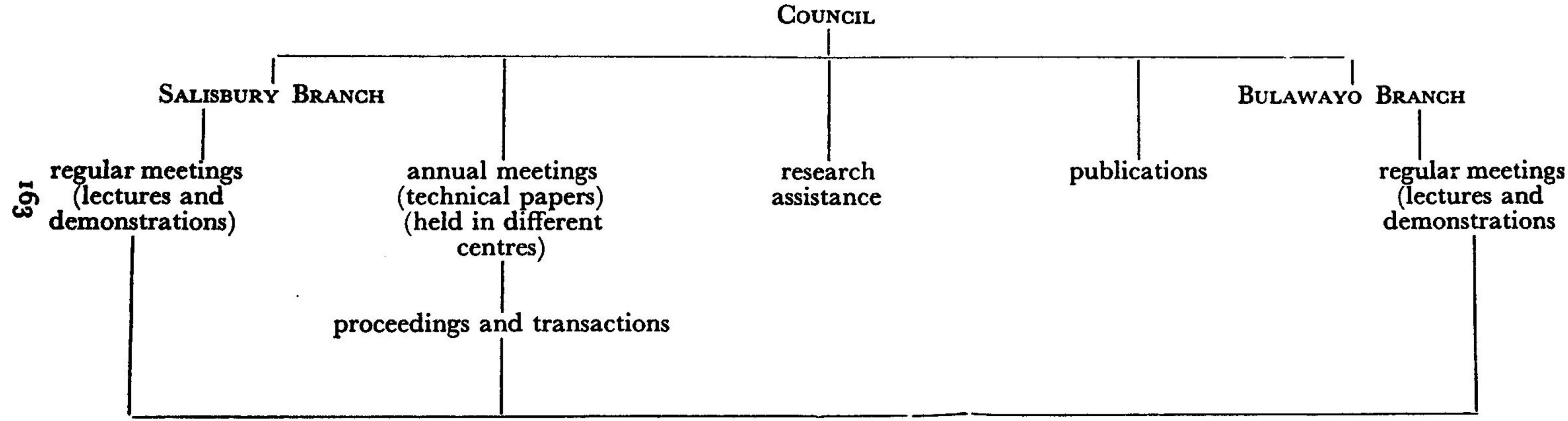
Aerial photographic surveys have been made of a few areas of the Colony chiefly in the gold mining districts.

A magnetic survey of South Africa, including Rhodesia, has been carried out at various times since 1898 with the aid of grants from the Royal Society, the British Association for the Advancement of Science, and various South African Governments. A lithographic press forming part of the Department is primarily used for the printing of maps compiled by the Department, and for other Government purposes.

APPENDIX I

RHODESIAN SCIENTIFIC ASSOCIATION

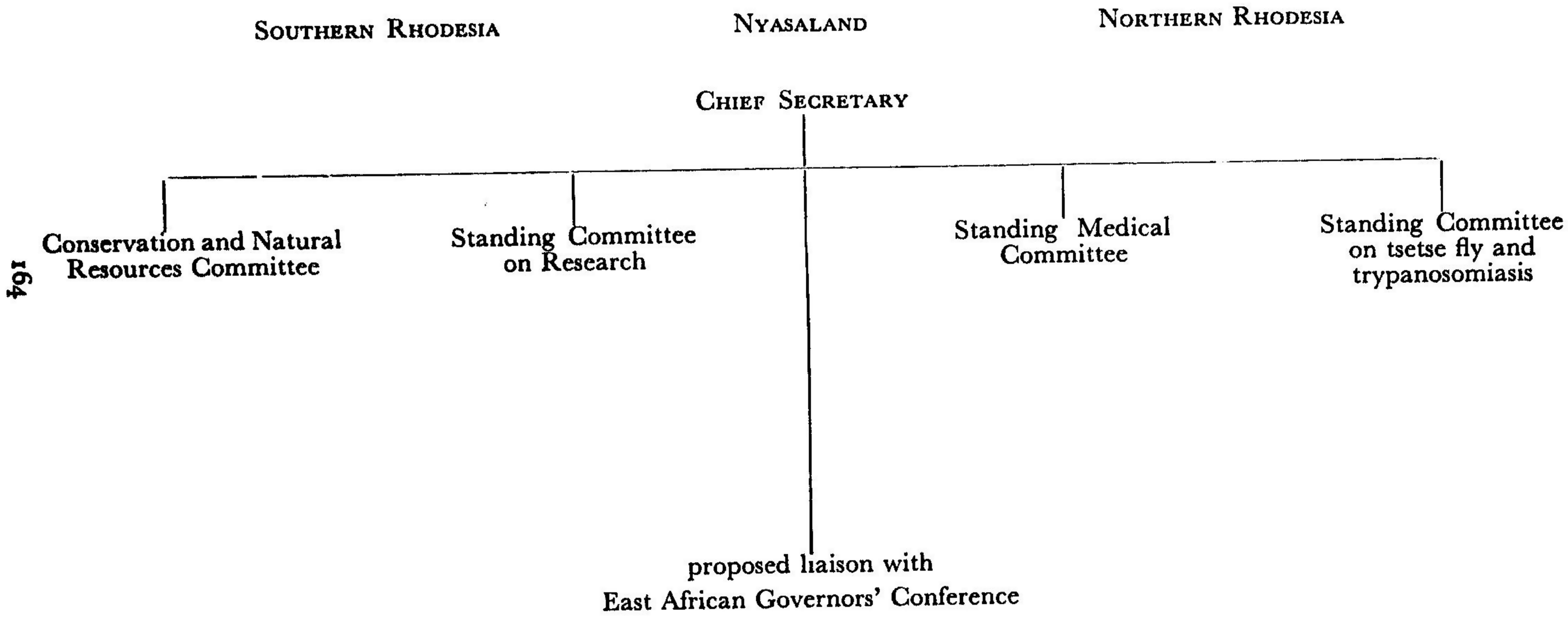
(Founded 1899)



Note : headquarters with library in Salisbury
popular lectures to educate public in science
otherwise endeavour to emulate British Association
financed by members' subscriptions, annual government grant and donations for specific purposes (e.g. Beit Trustees, State Lotteries Trustees, etc.)

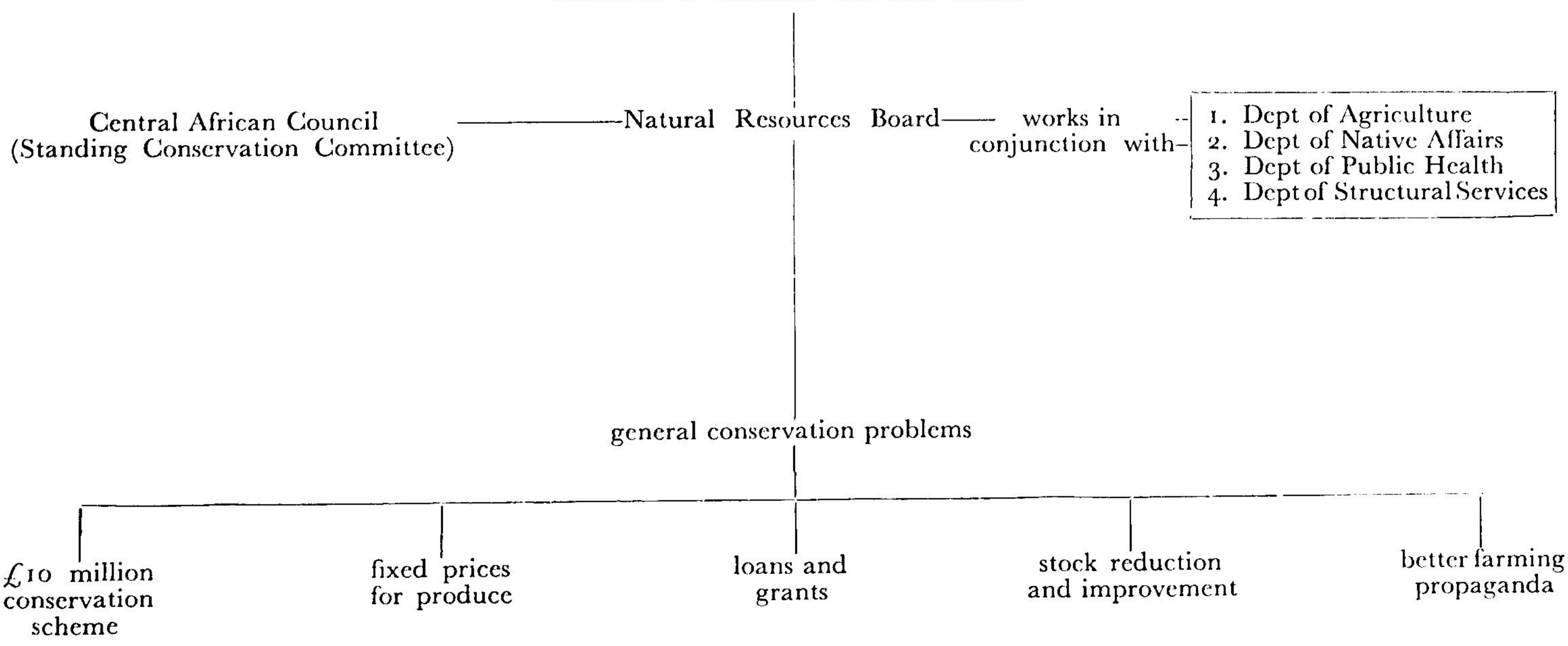
APPENDIX II

CENTRAL AFRICAN COUNCIL



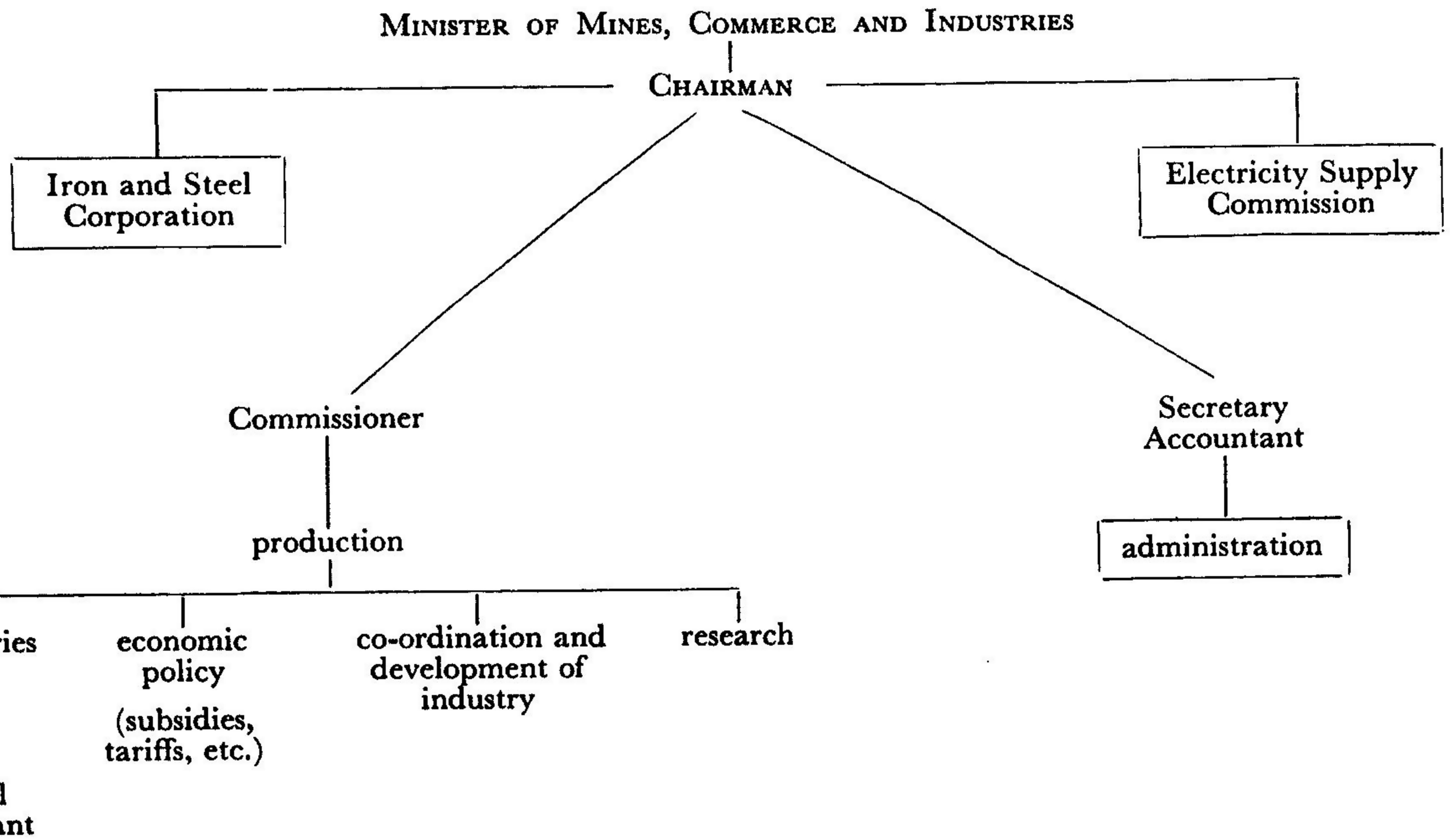
APPENDIX III

NATURAL RESOURCES BOARD (1942)



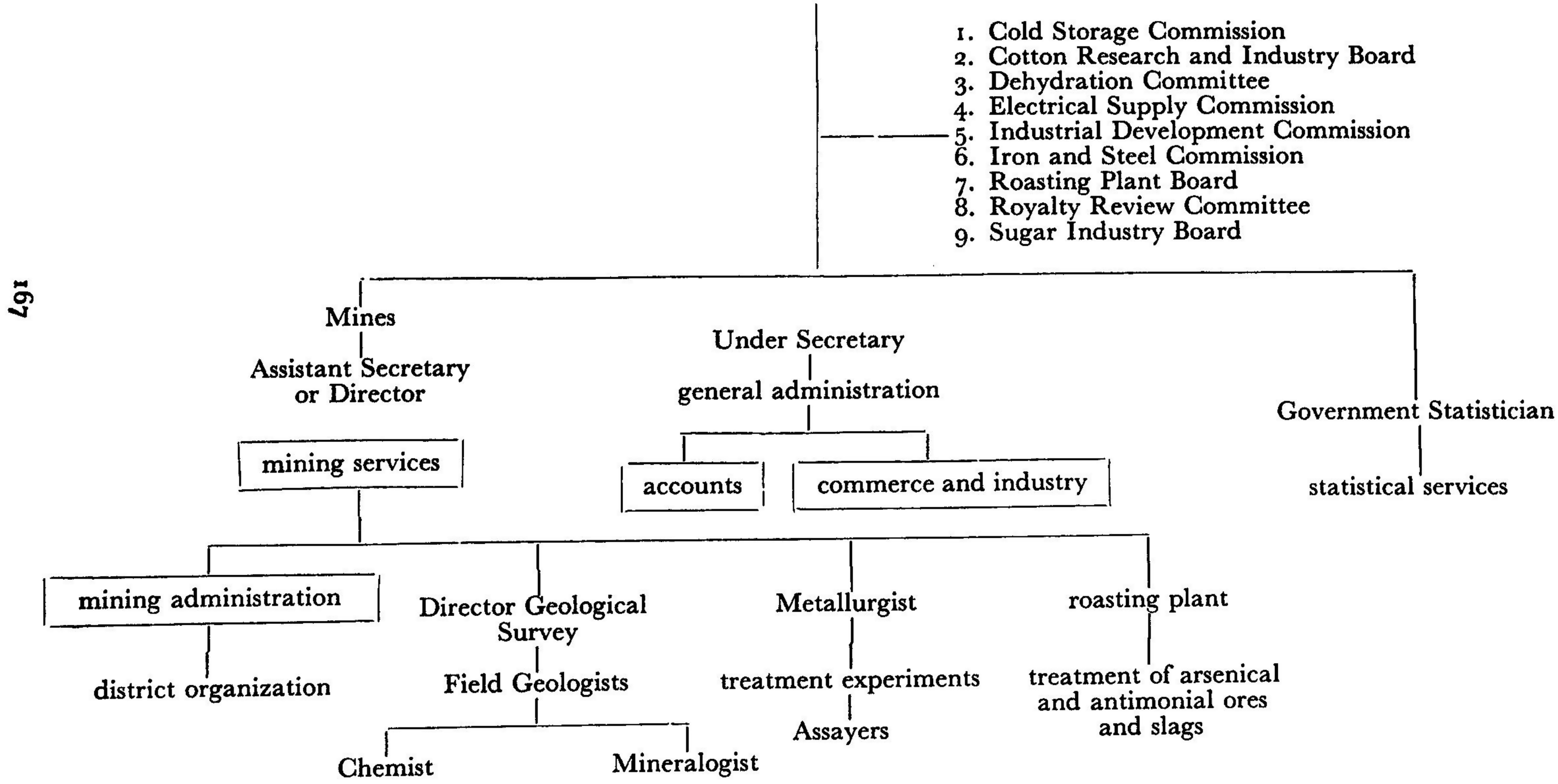
APPENDIX IV

INDUSTRIAL DEVELOPMENT COMMISSION



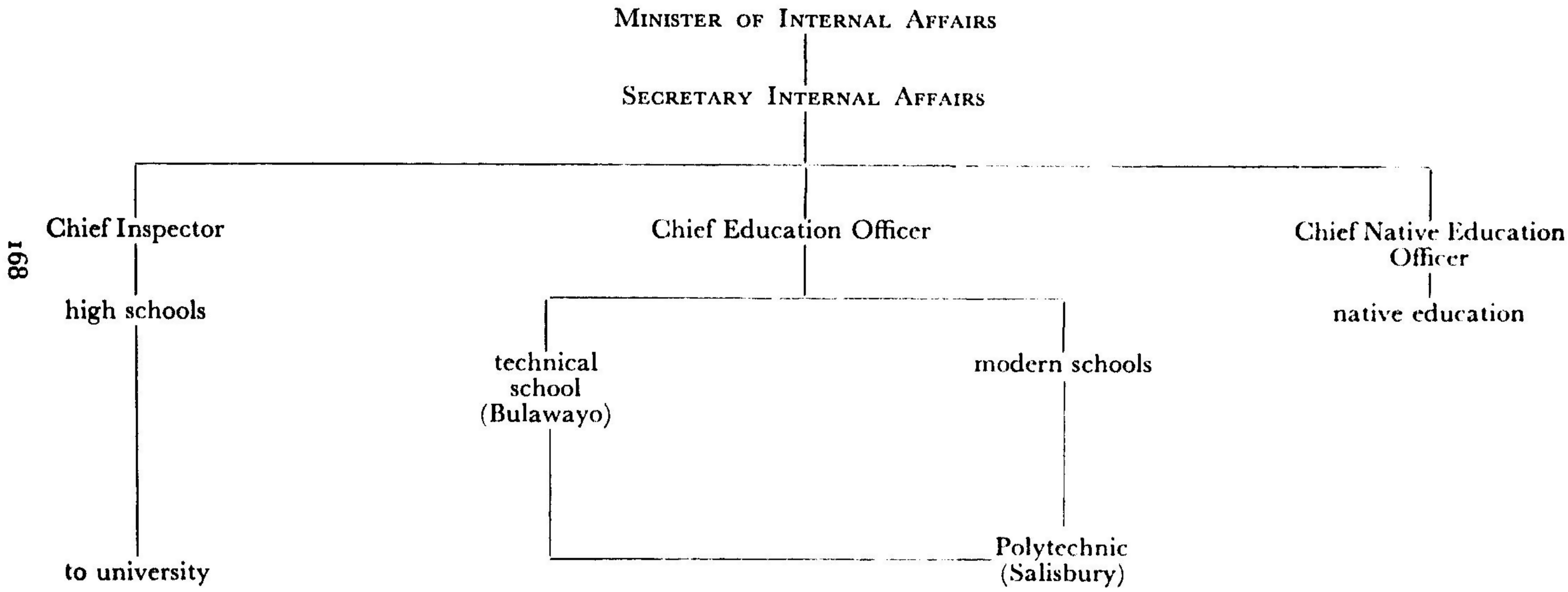
APPENDIX V

DEPARTMENT OF MINES AND ECONOMIC DEVELOPMENT



APPENDIX VI

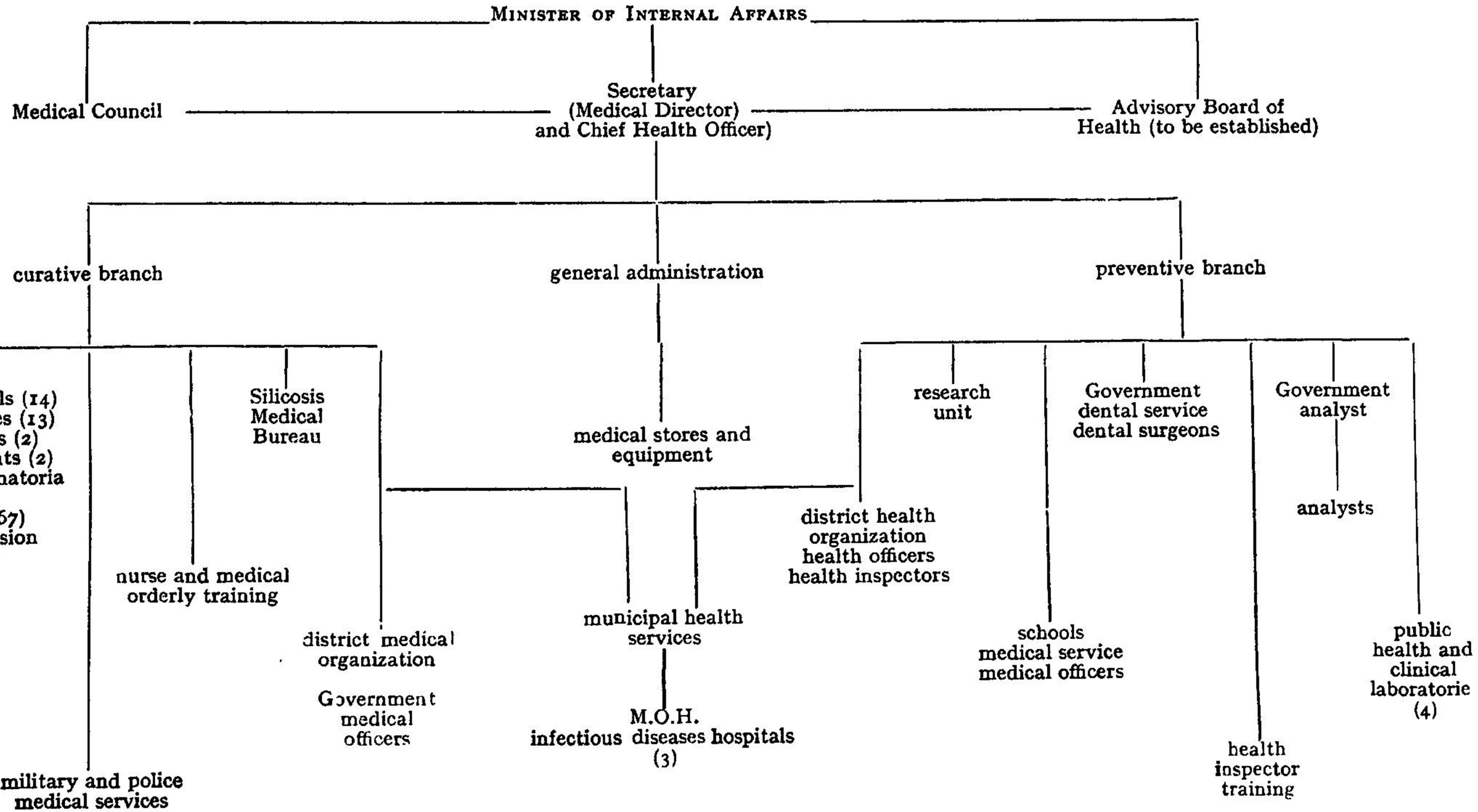
DEPARTMENT OF EDUCATION



(no higher education in science at present)

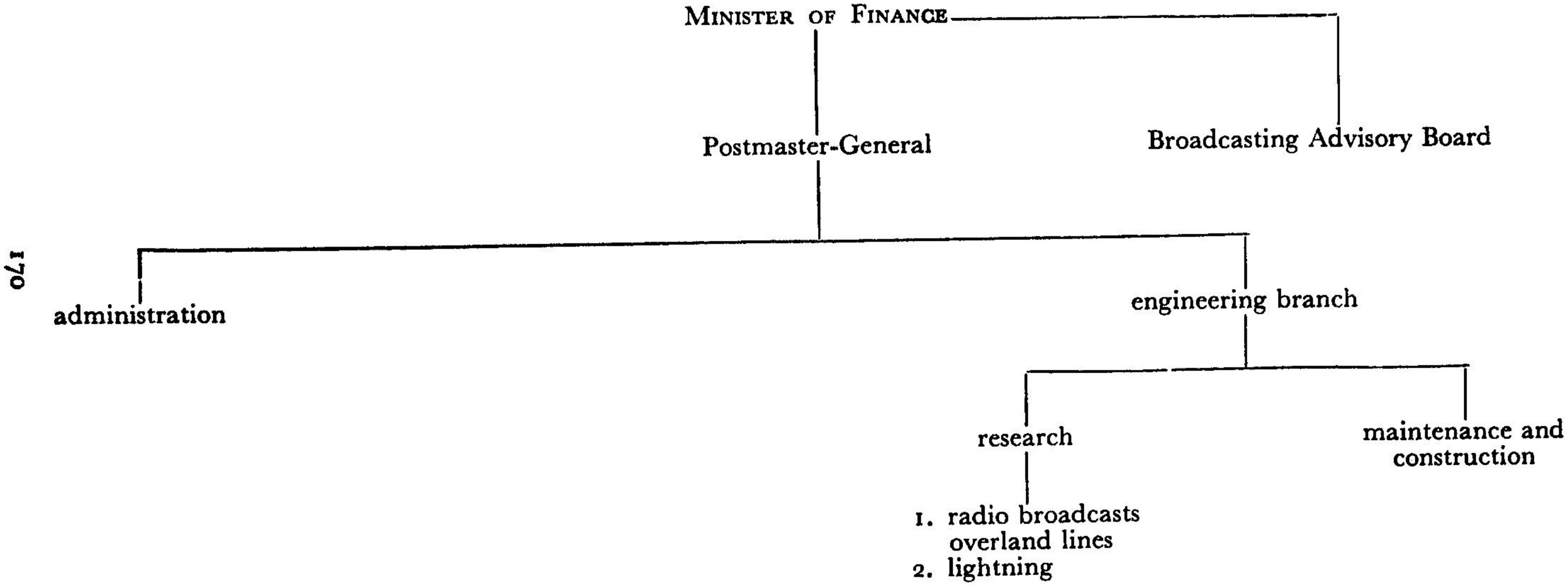
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DEPARTMENT OF PUBLIC HEALTH



APPENDIX VIII

DEPARTMENT OF POSTS AND TELEGRAPHS



DEPARTMENT OF AGRICULTURE AND LANDS

MINISTER OF AGRICULTURE AND LANDS

SECRETARY

Divisional Conservation Committee
Trypanosomiasis Committee
Plant Regulatory Board

scheduled states
- Union of South Africa
- Southern Rhodesia
- Northern Rhodesia
- Nyasaland
- Belgian Congo

- Cold Storage Commission
- Dairy Industry Control Board
- Farmers' Debt Adjustment Board
- Food Production Committee
- Land Settlement Board
- Maize Control Board
- Native Production and Marketing Board
- Natural Resources Board
- Pig Industry Control Board
- Sugar Industry Board
- Tobacco Marketing Boards
- Tobacco Research Board

Director — research and specialist services

- animal husbandry
- chemistry
- dairying
- entomology
- field husbandry and horticulture
- grassland research
- plant pathology and botany
- poultry industry
- tobacco industry

Under-Secretary — administration

- lands and land settlement
- marketing
- general administration and accounting

Director — veterinary services

- professional staff
- research staff
- administrative staff

Director — conservation and field services

- conservation and extension
- demonstration and training
- forestry
- native agriculture

outstations — field organization

outstations	field organization
agricultural schools	conservation staff
8 agricultural stations	demonstration farms staff
forestry outstations	extension staff
forestry areas	tsetse fly control staff
forestry school	veterinary staff

NOTES ON CURRENT SCIENTIFIC RESEARCHES IN THE UNITED KINGDOM

Note.—These " Notes " are not by any means exhaustive, but give a fairly comprehensive picture of research activity in the universities. The Notes were produced for a very specific purpose, namely, to provide delegates to the Empire Scientific Conference with information intended to be of interest to them. The omissions are very often at the request of the bodies concerned. Also the information applies to work in progress during the summer months of 1946 and a fair proportion of the " Notes " may already be out of date.

Sections B. C. D. and E. are little more than directories. In some cases detail with regard to researches at government or independent research stations has been supplied in the form of appendices. For details of researches in industry delegates were referred to *Industrial Research 1946* edited by Professor E. N. da C. Andrade and *Industrial Research and Development* by Sir Frank Heath and A. L. Hetherington. Each delegate was provided with copies of these books.

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SECTION A

ACADEMIC RESEARCH

I. UNIVERSITY OF ABERDEEN

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	*Anatomy Department* Professor R. D. LOCKHART	Action of muscles ; structure and function of ligaments ; structure and function of the central nervous system ; distribution and structure of the autonomic nervous system ; use of penicillin in prophylaxis and therapy.
Bacteriology	*Bacteriology Department* Professor J. CRUIKSHANK	The development of bacterial spores, especially Anthrax ; cellulose and decomposing bacteria, and the properties of bacterial cellulose ; Blood Groups, especially Rh Factor in relation to haemolytic anaemia of the new born, and blood transfusion.
Botany	*Botany Department* Professor J. R. MATTHEWS	Plant ecology and distribution ; mycorrhiza of British Orchids.
Chemistry	*Chemistry Department* Professor H. W. MELVILLE, F.R.S.	Physical chemistry of synthetic high polymers ; chemical kinetics ; photo-chemistry.
Embryology	*Anatomy Department* Professor R. D. LOCKHART	Genetics of new mutation of *Lebistes* (tropical Teleost fish) ; embryology and reproduction of *Lebistes*.
Geology and Mineralogy	*Department of Geology and Mineralogy* Professor J. C. PHEMISTER	Petrology of igneous and metamorphic rocks ; X-ray crystallography of minerals ; Devonian stratigraphy (O.R.S.) ; physiography of N. Scotland.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
	Natural Philosophy Department	
Natural Philosophy	Dr A. E. M. GEDDES	Seismology.
	H. D. GRIFFITH	Physical basis of clinical radiology.
	Pathology Department	
Pathology	Professor J. S. YOUNG	Factors concerned in dissemination of malignant tumours; healing of wounds.
	Materia Medica Department	
Pharmacology	Professor DAVID CAMPBELL	Pharmacological and therapeutic.
	Physiology Department	
Physiology	Professor E. W. H. CRUICKSHANK	Studies on the assessment of cardiac efficiency; liver cytoplasm in relation to protein nutrition.
	Natural History Department	
Zoology	Professor V. C. WYNNE-EDWARDS	Fisheries research; comparative physiology of the pituitary.

II. UNIVERSITY OF BIRMINGHAM

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	*Anatomy Department* Professor S. ZUCKERMAN, F.R.S.	The morphology and relationships of the primates and their reproductive physiology.
Botany	*Botany Department* Professor W. STILES, F.R.S.	Salt absorption and respiration; trace elements; diseases of strawberry plants.
Chemistry **(i) Organic and Inorganic**	*Chemistry Department* Professor W. N. HAWORTH, F.R.S.	Structure and properties of sugars, polysaccharides, starch, glycogen and cellulose, including their biological synthesis; enzymic synthesis of amylopectin; methods of separation and purification of enzymes; investigations on polysaccharides from physiological and bacteriological sources; study of pathogenic organisms and the constitution of ribonucleic acid and dioxyribonucleic acid and of the proteins which form part of their structure; conversion of cane sugar into substances of industrial importance.
(ii) Physical*	*Physical Chemistry Department*	X-ray crystallographic studies of the structure of organic molecules; kinetics of reactions in the solid state and at solid-liquid interface; physico-chemical aspects of the chemistry of fluorine and its compounds; electro-chemical behaviour of certain rare metallic compounds.
Engineering **(i) Civil Engineering**	*Civil Engineering Department* Professor C. BATHO	Theoretical and practical investigations of structures.
(ii) Electrical Engineering	*Electrical Engineering Department* Professor J. ROBINSON	The properties of dielectrics; dielectric breakdown; electronics.

* The department has a new osmometer for the determination of high molecular weights.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Engineering **(iii) Mechanical Engineering**	*Mechanical Engineering Department* Professor MUCKLOW	Problems concerning the sudden expansion of compressed gas into a system of pipes ; the hydrodynamic forces acting on the main members of hydraulic control valves ; piston-ring flutter.
(iv) Oil Engineering	*Oil Engineering Department* Professor F. H. GARNER	Rheological properties of non-Newtonian fluids ; magnetic rotation dispersion of hydrocarbons ; synthesis of pure hydrocarbons ; oxidation of hydrocarbons ; viscometry of pure hydrocarbons.
Mathematics	*Department of Mathematics and Mathematical Physics* Professor G. N. WATSON, F.R.S., and Professor R. E. PEIERLS, F.R.S.	Theory of Numbers ; Theory of Elementary Particles ; mathematical nuclear physics.
Medicine	*Department of Medicine*	Investigations in various branches of clinical medicine and surgery ; general social implications of medicine ; industrial medicine.
Metallurgy	*Metallurgical Department* Professor D. HANSON Professor AITCHESON	Fundamental problems of the metallic state. Industrial metallurgy.
Pathology	*Pathology Department* Professor HASWELL WILSON	Cancer research.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Pharmacology	*Pharmacology Department* Professor A. C. FRAZER	The mechanism of the absorption of fat from the intestine in animals and human subjects ; the nature of lipo-protein complexes and factors concerning their stability ; the mechanism of fat metabolism ; possible carcinogenetic effects of heated paraffin derivatives ; ketogenesis.
Physics	*Physics Department* * Professor M. L. OLIPHANT, F.R.S.	Nuclear physics including the acceleration of particles to high energies ; luminescence of solids ; thermal diffusion and related phenomena in gases ; the production of fast molecular streams by high speed rotors.
Physiology	*Physiology Department* Professor H. P. GILDING	Blood, tissue fluid and lymph exchanges ; functions of lymph glands ; renal functions in health or disease ; liver functions in health and disease ; metabolism and detoxication of sulphonamides and related compounds ; tissue culture in relation to normal growth and cancer ; the measurement of viscosity, surface tension and interface tensions of fluids of biological importance.
Zoology	*Zoology Department* Professor L. HOGBEN, F.R.S.	Statistical investigation of social and medical problems ; investigation of nutritional requirements of *Drosophila* for standardisation of environmental conditions in study of gene action ; quantitative studies of Wallerian degeneration of peripheral nerves ; distribution, structure and function of integumental glands of land Isopoda ; attraction of *Aedes aegypti* to its host ; insect behaviour with particular reference to the locust.

* The department has a cyclotron.

III. UNIVERSITY OF BRISTOL

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Physics	*H. H. Wills Physics Laboratory* Professor N. F. MOTT, F.R.S. Dr FRÖHLICH Dr POWELL	Structure of metallic conductors ; dielectrics and electronic processes in solids. Nuclear physics ; the use of the photographic plate for the quantitative study of high-energy particles.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Agriculture	*School of Agriculture* Professor Sir FRANK ENGLEDOW, F.R.S. Dr E. C. CHILDS H. H. NICHOLSON	Soil physics ; soil moisture and drainage problems.
	University Farm W. S. MANSFIELD	Experimental studies on crop and animal husbandry.
	Plant Breeding Institute Dr G. D. H. BELL (Acting Director)	Improvement, breeding methods, genetics, cytology and physiological studies in wheat, barley, oats, potatoes, sugar beet, beans, peas, lucerne and sainfoin.
	Horticultural Research Station D. BOYES	Vegetable and strawberry breeding ; nutrition of vegetables ; insect pests of vegetables.
	Institute of Animal Pathology C. A. MCGAUGHEY (Acting Director)	Vaccination against tuberculosis ; tuberculin reactions in cattle ; immunization against Brucellosis in cattle ; bacteriological studies ; haematology of pigs ; parasitology and anthelmintics ; chemistry of copper and trace elements.
	Plant Virus Research Station Dr K. M. SMITH, F.R.S.	Isolation and purification of plant viruses ; physical and chemical properties of viruses ; insect—virus relationships ; the virus diseases of potato, tomato, dahlia and other cultivated plants ; maintenance of stocks of virus-free potatoes.
	Animal Nutrition Institute *Animal Nutrition Section* H. E. WOODMAN	Protein requirements of bacon pigs ; utilization of fodder cellulose by pigs ; effect of changes in extraction rate on composition and feeding value of wheat by-products ; feeding value of horse chestnut, grazing and dried grass ; digestion and metabolism trials with pigs and sheep.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Agriculture (*continued*)	*Animal Nutrition Institute* (*continued*) *Animal Physiology* Dr J. HAMMOND, F.R.S. Dr A. WALTON	Experiments on growth and development of domesticated animals ; foetal development of sheep in relation to plane of maternal nutrition ; sexual physiology of the male ; factors affecting sperm production ; physiology of the spermatozoon ; artificial insemination ; endocrinology in relation to fertility of domesticated animals ; control of the sex cycle and ovulation in cattle and sheep.
	Poultry Genetics M. S. PEASE	Auto-sexing breeds of poultry ; inbreeding.
	Poultry Nutrition E. T. HALNAN	Protein and energy requirements for growth and egg production ; effect of nutritional factors on quality of product ; physiology of the digestive tract of the fowl ; nutritional problems of wartime rabbit production.
	Provincial Advisory Economics Service Dr A. W. MENZIES KITCHIN	Farm management survey on a sample of 400 farms ; study of land ownership ; economics of ley farming ; application of labour and machinery ; special cost studies with crops and stock.
Anatomy	*Department of Anatomy* Professor H. A. HARRIS	Studies on growth ; bone growth ; joints ; synovial fluid ; neurology and development of the nervous system ; pituitary and forebrain ; primate anatomy.
Astro Physics	**Observatory and Solar Physics Observatory* Professor F. J. M. STRATTON	Stellar photometry ; spectrophotometry ; solar and stellar spectra ; solar eruptions and streams of particles entering the ionospheres from the sun.

* Solar Physics Observatory has Newall 25″ refractor 3-foot reflector, spectroheliograph, Sheepshanks Condé equatorial spectrohelioscope and Rowland 21-foot grafting.

IV. UNIVERSITY OF CAMBRIDGE (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Biochemistry	*Sir William Dunn Institute of Biochemistry* Professor A. C. CHIBNALL, F.R.S.	Amino-acid composition and structure of proteins ; enzyme biochemistry ; microbiological chemistry.
Botany	*Department of Botany* Professor F. T. BROOKS, F.R.S.	Estimation of respiratory exchange in plants ; physiology of latex production ; uptake of solutes ; measurement of light intensity in woodlands ; plant ecology ; pollen analysis of peat deposits ; fungal and bacterial plant diseases ; soil fungi ; pure cultures of Protista ; fungus genetics ; genetical effects of radiation ; studies of plant populations ; fossil plants.
Chemistry **(i) Organic and Inorganic**	*University Chemical Laboratory* Professor A. R. TODD, F.R.S.	Synthetic and other studies on nucleotide co-enzymes and nucleic acids ; investigation of the potato eelworm hatching factor ; natural drugs ; chemotherapeutic studies ; chemistry of fluorine and the halogen fluorides ; organic compounds of silicon ; chemistry of silicon hydrides ; corrosion of metals.
(ii) Physical Chemistry	*Physical Chemistry Laboratory* Professor R. G. W. NORRISH, F.R.S.	Spectroscopy ; photochemistry ; reaction kinetics ; polymerization ; friction and related phenomena.
Colloid Science	*Department of Colloid Science* Professor E. K. RIDEAL, F.R.S.	Surface chemistry ; study of films, membranes and polymers, especially those of biological interest, by various physical methods including ultra centrifuge, infra-red and ultra short-wave absorption, and electron diffraction.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Engineering	*Engineering Laboratory*	
(i) Structures and Materials	Professor J. F. BAKER and J. W. RODERICK	The behaviour of steel structures and structural members in the plastic range ; the strength of light alloy structural members.
	Dr TIPPER	Investigation of brittle fracture in mild steel.
	A. H. A. HOGG	The deformation of non-Hookean solids under biaxial systems of stress.
	A. L. PERCIVAL and R. WECK	Fatigue strength of welded structures.
(ii) Vibrations	Professor J. F. BAKER and R. WECK	Investigation of residual stresses in steel structures.
	Dr R. D. DAVIES	Model experiments on the lateral oscillations of railway vehicles.
(iii) Fluid Mechanics	Professor Sir G. I. TAYLOR, F.R.S.	Instability of fluid surfaces in normal acceleration.
	A. M. BINNIE	Study of breakdown of laminar flow by a double refraction method ; oscillatory flow in pipe-lines ; vortex formation in circular weirs.
(iv) Electrical	Professor E. B. MOULLIN and C. W. OATLEY	Measurement of the aberrations of electrostatic electron lenses and other factors relative to the design of an electrostatic electron microscope ; various applications of electron optics.
(v) Heat Engines	A. L. BIRD	Investigations concerning the scavenging process in two-stroke cycle internal combustion engines, and the flow of engine exhaust gases through a suddenly opened valve or port.
	P. de K. DYKES	Piston-ring vibrations.
	W. E. WOODWARD and Dr D. G. CHRISTOPHERSON	Lubrication of journal bearings by liquids other than oils.
Experimental Medicine	*Department of Experimental Medicine* Professor R. A. MCCANCE	Kidney function of adult and infant animals and humans ; mineral metabolism ; chemistry of growth.
Genetics	*Department of Genetics* Professor R. A. FISHER, F.R.S.	Inbred lines of mice segregating for nearly all known factors ; quantitative inheritance and statistical design in improvement programmes ; polysomic inheritance in *Lythrum salicaria*.

IV. UNIVERSITY OF CAMBRIDGE (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Geodesy and Geophysics	*Department of Geodesy and Geophysics, Pendulum House Observatory* Professor Sir G. LENOX-CONYNGHAM, F.R.S.	Gravity ; seismology ; the study of heat flow from the earth.
Geology	*Sedgwick Museum* Professor W. B. R. KING Dr O. M. B. BULLMAN, F.R.S.	Palaeontological work on graptolites.
Metallurgy	*Department of Metallurgy* Professor G. W. AUSTIN	Corrosion of metals.
Mineralogy and Petrology	*Department of Mineralogy and Petrology* Professor C. E. TILLEY, F.R.S.	Ore microscopy ; high temperature investigations on mineral and rock synthesis ; X-ray study of minerals.
Parasitology	*Molteno Institute* Professor D. KEILIN, F.R.S. Dr BISHOP Mr TAIT	Cellular respiration and respiratory pigments ; helminthology and parasitic protozology.
Pathology	*Department of Pathology* Professor H. R. DEAN Dr R. I. N. GREAVES J. A. R. MILES	Serological problems ; Dr Greaves' apparatus for drying serum. Histology of experimental hepatitis.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Pharmacology	Dr E. B. VERNEY, F.R.S.	The anti-diuretic hormone.
Physics	* *Cavendish Laboratory and Mond Laboratory* Professor Sir LAWRENCE BRAGG, F.R.S.	Nuclear physics ; X-ray crystallography ; low temperatures (Mond Lab.) ; radio ; properties of metals.
Physiology	*Physiological Laboratory* Professor E.D. ADRIAN, F.R.S., Dr B.H.C. MATTHEWS, F.R.S., and E. H. WILLMOT Professor Sir J. BARCROFT, F.R.S. Dr FELDBERG Dr F. J. W. ROUGHTON, F.R.S., and Dr G. S. ADAIR, F.R.S. Dr RUSHTON and Dr HODGKIN	Sense organs and central nervous systems. Digestion in ruminants. Acetyl choline synthesis. Haemoglobin. Biophysics of nerve and muscle.
Psychology	*Department of Experimental Psychology* *The Psychological Laboratory* Professor F. C. BARTLETT, F.R.S.	Human performance of skilled operations under conditions of great heat and humidity ; problems of ' display ' and ' control ' ; perceptual ability and its relation to sensory thresholds ; human learning processes ; skill fatigue ; experimental study of thought processes ; uses and limits of intelligence tests.

* The Cavendish Laboratory possesses a cyclotron ; a 2-million volt equipment for the acceleration of particles ; a helium liquefier and an electron microscope.

IV. UNIVERSITY OF CAMBRIDGE (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Radio-therapeutics	*Department of Radiotherapeutics* Professor J. S. MITCHELL	Application of ultra-violet photomicrography to the study of the biochemical mechanism of the action of therapeutic doses of X and *gamma* radiations on normal and malignant cells; the use of radio phosphorous (P^{32}) in the investigation of the disturbance of cellular nucleic acid metabolism produced by therapeutic doses of radiations.
Zoology	*Department of Zoology* Professor J. GRAY, F.R.S. Dr V. B. WIGGLESWORTH, F.R.S. Dr C. F. A. PANTIN, F.R.S.	Mechanics of locomotion; insect physiology, particularly the properties of insect cuticle; nerve net of sea-anemones; terrestrial adaptation in invertebrates.
Embryology	*Strangeways Laboratory* Dr HONOR B. FELL	Studies of experimental embryology.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Agriculture	*Agricultural Chemistry Department* *(co-operating with Departments of Botany, Geography, Geology and Zoology)* Professor R. W. WHELDON BRYNMOR THOMAS	Regional survey of North Tyne Afforestation Area : investigations into the minor element content of meadow hay and various moorland species, e.g. drawmoss, flying bent, wire bent ; experiments on boron deficiency ; a study of the digestibility of mangels and of *Molinia coerulea ;* the direct sowing of forest trees (co-operating with the Forestry Commission) ; the restoration of opencast sites ; phosphate reserves in old permanent pasture ; moisture relationships in British soils under rotational conditions.
	Agricultural Economics D. H. DINSDALE	Farm management survey (Northern Counties).
Biophysics	*Physiology Department*	Circulatory adjustments to changes of posture ; circulatory changes in shock ; assessment of physical fitness.
Botany	*Botany Department* Professor J. W. HESLOP HARRISON, F.R.S.	Genetical, cytological and cytogenetical researches : Plant : Species hybrids of the Caryophyllaceae, Leguminosae, Rosaceae, Violaceae, Primulaceae and Salicaceae ; sex determination and sex anomalies in dioecious plants generally ; polyploidy in plants and its induction. Animal : Species hybrids, sex problems and polyploidy in the Lepidoptera ; origin of melanism in the Insecta ; evolution of island (Hebridean) faunas. Researches in peat and other deposits, with special reference to the post-glacial development of the vegetation of the North of England, Scotland and the Scottish Western Isles. The biochemistry of respiration in plants, and the possible relations between the activity of zymase and oxidation enzymes ; the external and internal conditions that induce zymasis in plants ; the effects on growth and development of depressed or disordered oxidation metabolism. Biogeographical investigations connected with the Quaternary geography of the Scottish Western Islands.

1. KING'S COLLEGE, NEWCASTLE-UPON-TYNE *(continued)*

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Civil Engineering	*Civil Engineering Department* Professor W. FISHER CASSIE	Investigation of flow over drowned weirs and broad crested spillways by means of hydraulic models ; determination of the torsional constants for large British Standard Beam sections by the soap film analogy ; the effect of dispersal agents and other admixtures in concrete ; soil mechanics.
Chemistry **(i) Organic**	*Chemistry Department* Professor G. R. CLEMO, F.R.S.	Isolation of active new plant principles ; the degradation and synthesis of certain known alkaloids and new terpenes ; plant products—yohimbine, solanidine, the santonins, and particularly eugenol in connexion with the research programme of the Colonial Products Research Council ; the mechanism of oxidation ; the photochemistry and radiation solutions and certain aspects of the action of carbon monoxide and hydrogen.
(ii) Inorganic and Physical Chemistry	*Chemistry Department* Professor H. L. RILEY, F.R.S.	Interstitial solid solutions in iron, nickel and other elements ; iron-nitrogen and iron-carbon systems ; a series of new terniary interstitial solid solutions ; the iron carbonitrides.
	Northern Coke Research Laboratory	The nature of coking coals and the molecular mechanism of carbonization ; the molecular character of bitumens in coking coal by X-ray diffraction methods ; crystallographic character of those forms of carbon usually termed amorphous ; humins and humic acids ; solvent extraction of coal.
Electrical Engineering	*Electrical Engineering Department* Professor J. C. PRESCOTT	The characteristics of synchronous governors ; circuit rupturing by sliding contacts ; vacuum-tube circuits and applied electronics.
Geography	*Geography Department* Professor G. H. J. DAYSH	River evolution in north-east England ; methods of portraying terrestrial relief on topographic maps ; techniques of distributional mapping.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Geology	*Geology Department* Professor H. G. A. HICKLING, F.R.S.	Microscopic structure of coals, cannels, torbanites and oil shales ; variation of coal rank in relation to coalfield structure ; studies of spore-distribution in coals ; petrology and classification of British carboniferous igneous rocks ; sedimentary petrology of local carboniferous rocks.
Histology	*Physiology Department* Professor D. BURNS	Changes in the pituitary body under nerve stimulation.
Mathematics	*Mathematics Department* Professor G. R. GOLDSBROUGH, F.R.S. Professor A. C. OFFORD	Extremum problems for functions of a complex variable ; summation of Fourier series ; integral functions ; random sequences ; problems in the dynamical theory of ocean tides and currents.
Mechanical and Marine Engineering	*Mechanical and Marine Engineering Department* Professor C. J. HAWKES	Torsional constant for I beams ; equivalent lengths of crankshafts for estimating the natural frequencies of vibration of engine systems.
Metallurgy	*Metallurgy Department* Professor C. E. PEARSON	Stress-corrosion cracking in welded mild steel.
Mining	*Mining Department* Professor G. POOLE	Mine ventilation ; Miners' nystagmus ; gas evolution in coal seams and safety factors ; mine dusts ; colliery wastes, and other mining problems.
Pathology	*Pathology Department* Professor A. F. B. SHAW	Phosphateses in relation to cancer of the prostate.

1. KING'S COLLEGE, NEWCASTLE-UPON-TYNE (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Pharmacology	*Physiology Department*	The action of extracts of the *Cortex Suprarenalis* ; the action of guanidine and its derivatives.
Physiology	*Physiology Department* Professor D. BURNS	Quantitative investigations on chromatographic adsorption ; factors affecting the carcinogenetic activity of hydrocarbons ; the purification of esterases ; microtitration methods ; mammalian ammonia excretion ; the growth of bone.
Physics	*Physics Department* Professor W. E. CURTIS, F.R.S.	Sound, especially supersonics ; fluid motion ; spectroscopy.
Zoology	*Zoology Department* Professor A. D. HOBSON *Dove Marine Laboratory*	The physiology and culture of nematode worms parasitic in animals ; physiology and control of the potato root eel worm ; metabolism and body size in poikilosmotic animals ; osmotic regulation in animals ; studies in insect populations ; intra-cellular digestion in sea anemones. Sensory equipment and behaviour of marine fishes ; ecology and distribution of the British marine coastal fauna ; local inshore fishery problems.

2. DURHAM DIVISION SCIENCE DEPARTMENTS

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botany Department* Dr D. H. VALENTINE	Experimental taxonomy of British species of viola, primula and potentialla ; respiration of roots ; limnology.
Chemistry	*Chemistry Department* Professor F. A. PANETH	Helium researches ; chemistry of radioactive substances ; chromatographic studies.
Geology	*Geology Department* Professor L. R. WAGER, F.R.S.	Geology of East Greenland ; petrology of alkaline rocks ; coal measure stratigraphy.
Mathematics	*Mathematics Departmen* Professor J. L. BURCHNALL	The algebra of differential equations ; the elastic theory of aeolotropic substances.
Physics	*Physics Department* Professor J. E. P. WAGSTAFF	Atmospheric electricity ; properties of complete dielectrics.

VI. UNIVERSITY OF EDINBURGH

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Astronomy	*Department of Astronomy and Royal Observatory, Edinburgh* Professor W. M. H. GREAVES, F.R.S.	Measurement of total line intensity of the hydrogen lines in stars of type 'B'—the spectra are being obtained with a 2-prism Hilger spectrograph attached to a 36-in. reflecting telescope and are being analysed with a microphotometer employing a Moll thermo-couple and galvanometer.
Bacteriology	*Department of Bacteriology* Professor T. J. MACKIE	Studies on : viruses bacteriophage antibiotics.
Biochemistry	*Department of Biochemistry* Professor G. F. MARRIAN, F.R.S.	Problems connected with the chemistry and biochemistry of the steroids, including the nature of the conjugated steroids in the urine of pregnant mares ; the determination of pregnanediol in human urine ; the chemical estimation of oestrogens in urine ; the properties and physiological role of β-glucuronidase ; chemistry of the cell nucleus.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry	*Department of Chemistry* Professor J. P. KENDALL, F.R.S.	Colloids and surface chemistry : Study of the properties of aqueous solutions of halogenated phenanthrene sulphonic acids with a view to the elucidation of the nature and mode of formation of the colloidal micelles in these systems. Qualitative inorganic analysis : The application of modern sensitive and selective reagents in the systematic qualitative analysis of inorganic substances on a semi-micro scale. Photochemistry : Photoexpansion of chlorine and chlorine reactions with toluene ; latent image formation in thallous bromide gelatin systems. Aromatic chemistry : Naphthalene, fluoranthene and anthraquinone ; heterocyclic chemistry in general ; indole, carbazole and indazoles ; benzanthrone and its derivatives. Studies on seaweed polysaccharides ; carbohydrate ethereal sulphates.
Genetics	*Department of Animal Genetics and Institute of Animal Genetics* Dr A. W. GREENWOOD	Livestock genetics of cattle with special reference to the study of environmental factors affecting milk production. Pigs : problems of litter size and weight employing inbred and cross-bred matings. Effects of genetics and other influences on spontaneous mutation rate of Drosophila. Cytological studies with special reference to chromosomes. Cancer : the sterility, abnormal fat metabolism and peculiar form of cancer induction associated with the ' yellow ' gene in mice.

VI. UNIVERSITY OF EDINBURGH (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Geology	*Department of Geology* Professor A. H. HOLMES, F.R.S.	Studies of granite complexes and phenomena of granitization in Scotland and Ireland. Boulders and pebbles of Highland and other rocks in the Old Red Sandstone of Kincardineshire. The tertiary complex of St Kilda. Potash-rich volcanic rocks of Uganda. Structural and correlation problems of the Grampians. Lower tertiary foraminifera of India and West Africa. Correlation of coal seams by spores. Lower palaeozoic fossils of the Pentland Hills.
Materia Medica	*Department of Materia Medica* Professor J. H. GADDUM, F.R.S.	
Mathematics	*Department of Mathematics* Professor Sir E. J. WHITTAKER, F.R.S.	
Medicine	*Department of Medicine* Professor L. S. P. DAVIDSON	Haematology ; rheumatic diseases.
Natural Philosophy	*Department of Natural Philosophy* Professor N. FEATHER, F.R.S.	Research into the *beta* and *gamma* radiations of radioactive bodies, both natural and artificial, with the use of a double β-ray spectrograph.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Pathology	*Department of Pathology* Professor A. M. DRENNAN	
Physiology	*Department of Physiology* Professor I. DE BURGH DALY, F.R.S.	Investigation of pulmonary vasomotor using the perfused whole animal. Measurement of the diffusion constants of gases. Measurement of heats of reaction. Experiments on the transmission of nerve impulses across hypothalamic synapses, with special reference to the hypothalamic-pituitary connexions ;—the method used involves the direct application of drugs to the various nuclei concerned. Investigations of the renal clearance and blood flow in man in certain hypothalamic and endocrine disorders. Laboratory methods in the production of controlled electrical stimulation devices. Regeneration and recovery of motor nerves in war injury. Results of facial nerve grafting and transplant in various injuries in the skull.
Prehistoric Archaeology	*Department of Prehistoric Archaeology* Professor V. G. CHILDE	
Preventive and Social Medicine	*The Usher Institute* Professor F. A. E. CREW, F.R.S.	Medico-sociological and demographical investigations ; application of biological knowledge to human and social affairs.

VI. UNIVERSITY OF EDINBURGH (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Psychology	*Department of Psychology* Professor J. DREVER	Rehabilitation of patients with brain lesions (in co-operation with Brain Injuries Unit at Bangour). The comparative study of existing projection test material, and the production of new material both for children and adults. The validation and modification of a selection scheme for apprentices to the printing trade. An investigation will probably have started on interview technique. An investigation into the effects of stimulus patterning in learning experiments.
Surgery	*Department of Surgery* Professor J. R. LEARMONTH	Investigation of intra-abdominal visceral reflexes. Process of repair in ligaments. Physiological effect of arterio-venous communications. Clinical features and repair of peripheral nerves.
Therapeutics	*Department of Therapeutics* Professor D. M. DUNLOP	
Zoology	*Department of Zoology* Professor J. RITCHIE	

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
	Anatomy Department	
Anatomy	Professor W. J. HAMILTON	Early mammalian development.
	Dr WYBURN	Placentation in the rodents.
	Dr MONIE	Placental permeability.
	Dr HARRISON	Certain aspects of the physiology of reproduction.
	Bacteriology Department	
Bacteriology	Professor C. H. BROWNING, F.R.S.	Chemotherapeutic studies, particularly in relation to trypanosomiasis; chemical carcinogens.
	Botany Department and Stevenson Laboratory	
Botany	Professor J. WALTON	Palaeobotany (Carboniferous); fertilization in Bryophyta.
	Dr S. WILLIAMS	Experimental morphology of Pteridophyta.
	Dr G. BOND	Nitrogen fixation by nodule-bearing plants.
	Dr G. F. ASPREY	Respiration in Thallophyta.
	Dr ELSIE CONWAY	Bracken investigation and autecology of agar producing Algae.
	Chemistry Department	
Chemistry		
(i) Physical	Professor J. M. ROBERTSON, F.R.S. and Dr T. H. GOODWIN	Molecular structure; X-ray diffraction methods.
	Dr S. T. R. S. MITCHELL	Photolysis of chloro-nitroso compounds; studies in circular dichroism.
	Dr G. THOMSON	Dipole moments in relation to resonance.
	Dr J. BELL	Comparison of physical properties of hydrates and the corresponding deuterates.
(ii) Inorganic	Dr J. MAIR	Investigations of heteropoly acids and their salts.
(iii) Organic	Professor J. W. COOK, F.R.S.	The chemistry of colchicine and the synthesis of its derivatives; chemotherapy of malaria; synthesis of fused-ring structures, carbocyclic and heterocyclic; investigations on azulenes; attempts to find new growth-inhibitory compounds.
	Dr T. S. STEVENS	
	Dr J. D. LOUDON	
	Dr S. H. TUCKER	Derivatives of carbazole and fluoranthene.
	Dr T. S. STEVENS	Studies of molecular rearrangement.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Genetics	*Genetics Department* Dr G. PONTECORVO	Genetics of micro-organisms.
Geology	*Geology Department* Professor A. E. TRUEMAN, F.R.S. Dr J. WEIR Dr D. LEITCH Dr E. D. CURRIE Dr G. W. TYRRELL B. H. BARRETT	Geology of British coalfields ; carboniferous palaeontology. Mesozoic echinoids ; serial sections in the study of ammonites. Petrology of igneous rocks. Petrology of sedimentary rocks.
Physiology	*Physiology Department* Dr G. H. BELL Dr H. N. MUNRO Dr H. S. D. GARVEN	Physiology of bone ; haemoglobin. Protein metabolism. Histology of nerve supply to organs.
Zoology	*Zoology Department* Professor C. M. YONGE, F.R.S., and others C. W. PARSONS Dr M. W. JEPPS J. A. DOWNES and others Dr O. LOWENSTEIN Dr J. D. ROBERTSON Dr H. D. SLACK Dr H. F. STEEDMAN	Physiology and biology of marine mollusca ; reproduction and moulting of marine crustacea. Vertebrate morphology. Protozoology and helminthology. Entomology. Physiology of sense organs. Body fluids of marine invertebrates. Fresh-water biology. Histological methods—' ester wax ' media.

VIII. UNIVERSITY OF LEEDS

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botany Department* Professor IRENE MANTON Dr R. D. PRESTON	Chromosome structure by ultra-violet microscopy. X-ray analysis for cell-wall structures.
Chemistry	*Chemistry Department* Professor M. G. EVANS Professor E. G. COX Professor F. CHALLENGER *Colour Chemistry Department* Professor F. M. ROWE, F.R.S.	Kinetics of polymerization ; kinetics of oxidation-reduction reactions. Studies of the solid state. Biological methylation, particularly with respect to mould fungi ; heterocyclic sulphur compounds. Colour chemistry.
Engineering	*Engineering Department* Professor W. T. DAVID Dr R. H. EVANS	Unreleased energy in flame gases. Structural engineering ; pre-stressed concrete.
Fuel and Metallurgy	*Fuel and Metallurgy Department* Professor D. T. A. TOWNEND	Collaborative research with the Gas Research Board includes : high-pressure gasification of coal ; catalytic synthesis of methane ; radiant heating ; combustion ; high-pressure reactions ; flame stability ; refractories ; the scaling of steels.
Geology	*Geology Department* Professor W. Q. KENNEDY	Metamorphism in calcareous rocks.
Medicine	*School of Medicine* Professor M. J. STEWART Professor A. DURWARD Professor J. W. MCLEOD, F.R.S. Professor R. D. PASSEY	Industrial pulmonary diseases ; pathology of peptic ulcers. Blood supply and growth of nerves ; hair growth cycles. Investigation of virulence of various diphtheric strains. Cancer investigation in various connexions particularly in the field of industry ; heredity ; the keratin of cancer and the milk factor in breast cancer.

VIII. UNIVERSITY OF LEEDS (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Mining	*Mining Department* Professor J. W. WHETTON	Geophysical prospecting.
Physics	*Physics Department* Professor R. WHIDDINGTON, F.R.S. Professor E. C. STONER, F.R.S. J. EWLES Dr G. W. BRINDLEY	Magnetic properties of substances. Luminescence. X-ray studies.
Textiles	*Textile Industries Department* Professor J. B. SPEAKMAN Professor W. T. ASTBURY, F.R.S.	Reactivity of natural and synthetic fibres from the chemical standpoint. Molecular structure of fibres and biological tissues.
Zoology	*Zoology Department* Professor E. A. SPAUL	Insect metamorphosis ; sewage purification ; endocrines and reproduction ; physiology of Cestodes.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	*Department of Anatomy* Professor W. H. WOOD	Innervation of bone.
Bacteriology	*Department of Bacteriology* Professor A. W. DOWNIE	Staphylococcal bacteriophages ; *Variola* and related viruses.
Biochemistry	*Johnston Laboratories* Professor R. A. MORTON	Vitamins A and A_2 and their mode of action ; spectrophotometry applied to biochemical problems ; detoxication mechanisms.
Botany	*Hartley Botanical Laboratories* Professor J. MCLEAN THOMPSON	Angiosperms ; plant behaviourism ; phyllotaxis ; root-parasitism ; marine algae.
Chemistry **(i) Inorganic and Physical**	*Muspratt Laboratories* Professor W. C. M. LEWIS, F.R.S.	Measurement of electrophoretic mobilities ; photo-electric study of gold sols ; kinetics of halogen reactions in solution ; oxygen over-voltage ; anodic behaviour of metals ; measurement of heats of fusion.
(ii) Organic	*Organic Chemistry Laboratory* Professor A. ROBERTSON, F.R.S.	Organic chemistry and microbiological chemistry, including studies on the chemistry, constitutions and synthesis of natural products, colouring matters, and alkaloids.
iii) Industrial	*Gossage Laboratories* Professor T. P. HILDITCH, F.R.S.	Autoxidation of unsaturated fatty compounds.
Chemotherapy	*Warrington Yorke Department of Chemotherapy,* *Liverpool School of Tropical Medicine* Dr E. M. LOURIE	Investigation of compounds used or intended to be used against parasitic infections ; synthesis and trial of potential trypanocidal agents.

IX. UNIVERSITY OF LIVERPOOL (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Engineering	*Walker and Harrison-Hughes Engineering Laboratories* Professor G. E. SCHOLES	Photo-elastic investigation into stress distribution in notched beams and high pressure hydraulic cylinders.
Electronics	* *Electrical Engineering Department* Professor J. M. MEEK	High voltage investigations into the electrical breakdown of gases.
Entomology and Parasitology	*School of Tropical Medicine, Department of Entomology and Parasitology* Professor R. M. GORDON	The life-cycle of *Litomosoides carinii* in *Liponyssus bacoti*, and its transmission to the cotton rat ; primary phase of malaria ; the testing of gammexane against various arthropods ; the life-cycle and habits of British Culicoides ; the maintenance and rearing of various strains of arthropods.
Mathematics	*Department of Applied Mathematics* Professor L. ROSENHEAD, F.R.S.	Computational methods ; the classification of mathematical tables.
Physics	† *George Holt Physics Laboratory* Professor SIR JAMES CHADWICK, F.R.S.	Experimental nuclear physics ; production of radioactive elements neutronics ; β-ray spectrography ; cosmic rays.
Physiology	*Department of Physiology* Professor W. H. NEWTON	Movements and secretions of the alimentary tract ; culture of bone ; metabolism in pregnancy.

* Equipment includes a one million volt impulse generator, a 300 kV transformer, and a continuously evacuated high speed Cathode-ray oscillograph.

† Equipment : cyclotron, mass spectrograph, cloud chamber, electronic detecting devices.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Surgery	*Department of Surgery* Professor C. A. WELLS	The use of curare in general anaesthesia in man.
Tidology	*Liverpool Observatory and Tidal Institute* Dr A. T. DOODSON, F.R.S.	Analysis of tidal observations.
Tropical Medicine	*School of Tropical Medicine Department of Tropical Medicine* Professor B. G. MACGRAITH	Physiological and pathological processes concerned in tropical diseases such as malaria, blackwater fever and sprue ; chemotherapy of tropical disease, including malaria, kala-azar and schistomosiasis ; pharmacology of chemotherapeutic drugs, including paludrine and mepacrine.
Zoology	*Department of Zoology (and Oceanography)* Professor J. H. ORTON	Biology of the oyster, the salmon and *patella* ; marine biology of the Mersey estuary ; studies in endocrinology ; Arachnids, Oligochaetes ; genetics of cattle.
	Marine Biological Station, Port Erin, Isle of Man Naturalist in charge : J. A. BRUCE	Herring—age groups of shoals, migration, breeding ; fish hatching—plaice, cod, lobster ; biology of *patella*—population study and behaviour ; amphipod ecology ; marine algae—rate of growth, breeding.

X. UNIVERSITY OF LONDON

1. Bedford College

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botany Department* Professor W. Neilson Jones Dr M. M. C. Rayner Dr Brown Dr Warburg	Mycorrhizal, compost and soil fertility problems especially in relation to forestry (in conjunction with the Forestry Commission). Root metabolism. British vegetational and systematic problems.
Physics	*Physics Department* Professor H. T. Flint	Development of a method for measuring dielectric constants and absorptions short-wave lengths in polar substances ; nuclear field theories.
Zoology	*Zoology Department* Professor H. M. Fox, F.R.S.	Metabolism of aquatic invertebrates ; haemoglobin.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Department of Botany* Dr S. E. JACOBS	Bacteriological : antibiotic action ; specific bacterial diseases of plants ; mechanism of action of antiseptics ; action of high-frequency electric fields on bacteria.
	Dr H. W. BUSTON *Imperial College Field Station, Slough, Bucks.*	Biochemical : fungal decomposition of cellulose ; mode of action of certain growth inhibitors ; synthesis of certain polypeptides.
	Professor W. BROWN, F.R.S.	Mycological and plant pathological : physiological aspects of parisitism ; the persistence of pathogenic organisms in soils ; antibiotic action ; plant diseases, particularly of lettuce, tomato, potato, seakale and certain ornamentals.
Chemistry **(i) Organic**	*Department of Organic Chemistry* Sir IAN HEILBRON, F.R.S., Dr E. R. H. JONES, Dr A. H. COOK, Dr L. N. OWEN, Dr E. A. BRAUDE	Investigations on chemotherapeutic agents of various types, especially penicillin and related antibiotics; BAL-intrav ; polyenes, sterols and acetylene chemistry ; ultraviolet light absorption of organic compounds.
(ii) Inorganic and Physical	*Department of Inorganic and Physical Chemistry* Professor H. V. A. BRISCOE and Dr J. A. KITCHENER	Properties of ion-exchange synthetic resins.
	Professor H. V. A. BRISCOE and B. ATKINSON	Photochemical gas reactions.
	Dr A. J. E. WELCH	High temperature chemistry of metal fluorides ; development of methods for studying the chemistry and kinetics of solid-phase reactions ; high temperature reduction processes, especially chemistry of suboxides and other sub-compounds ; inter-relationships of metal oxide and sulphide systems at high temperatures.

2. IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry (ii) Inorganic and Physical (*continued*)	*Department of Inorganic and Physical Chemistry*	
	Dr E. R. ROBERTS Dr E. R. S. WINTER	Separation of isotopes ; isotope abundance measurements.
	Dr J. A. KITCHENER	Photochemical reactions in solids ; non-stoicheiometry in zinc oxides.
	A. G. POLLARD A. W. MARSDEN J. HANNEN	Chemistry of soil solutions, its application to the problems of plant nutrition and soil fertility ; chemistry of potting soils and composts ; soil fumigations.
	Dr R. F. HUDSON	Vapour phase hydrolysis.
	Dr J. O'M. BOCKRIS	Electrolytic polarization with special reference to the activation over potential.
	Dr D. H. R. BARTON	Theories of optical rotatory power and their application to the elucidation of molecular structure.
	J. F. HERRINGSHAW	Electrochemical study of the reduction of organic compounds with particular reference to irreversible reductions by dissolving metals and by cathodic action.
Chemical Engineering and Applied Chemistry	*Department of Chemical Engineering and Applied Chemistry*	
	Professor Sir ALFRED EGERTON, Sec.R.S. Professor D. M. NEWITT, F.R.S.	Chemical technology and chemical engineering, fuel technology (combustion) ; high pressure (20,000 atmospheres) ; low temperature (utilization of Methane).
	Professor G. I. FINCH, F.R.S.	Physics and chemistry of surfaces (electron diffraction).

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Engineering	*Department of Civil Engineering and Surveying*	
(i) Civil Engineering	Professor A. J. S. PIPPARD	Structural research : distribution of stress in ships' hulls ; reduction of flexural rigidity of ships' hulls ; stresses in high building frames due to wind pressures ; determination of secondary stresses in roof trusses ; the strength and stiffness of thin web plates in welded plate girders ; stress distribution in materials subjected to stresses above yield point. Stress distribution round stiffened openings in plates.
	Dr C. M. WHITE	Fluid mechanics and hydraulics research : mechanism of erosion of river beds ; action of crest gates for spillway of Cluny Dam ; thermal currents and turbulent mixing in model of proposed reservoir ; wave action in sea bed—various gravity wave problems ; mechanism of sealing devices ; development of special sand for river and coastal models ; flow in divergent passages.
	Department of Electrical Engineering	
(ii) Electrical Engineering	Professor C. L. FORTESCUE	Damping of electrical instruments ; high frequency bridges operating 50 megacycles and other high frequency measurements ; cathode-ray-oscillograph and klydonographic investigations of surge phenomena ; mathematical and experimental investigations of electrical servo-mechanisms ; circuit heaters and arc-control.
	Department of Mechanical Engineering and Motive Power	
(iii) Mechanical Engineering	Professor C. H. LANDER	Heat transmission ; high-speed gas flow in channels ; mixing of hot and cold gas streams, applied to combustion in gas turbines ; scale effect on size and radiating properties of gas flames ; propulsion of visco-elastic liquids ; properties of particles as applied to mining processes ; production of powdered materials ; power metallurgy.

2. IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Entomology	*Department of Zoology and Applied Entomology (see also 'Zoology')* A. E. H. HIGGINS	The establishment and maintenance of insect stocks for teaching and research, and methods of breeding.
	Dr O. W. RICHARDS	Experimental work on the grain weevil, *Calandra*; classification of parasitic Hymenoptera found in warehouses; the biology and classification of social wasps.
	P. FREEMAN	Classification of cotton-stainers (Hemiptera).
	Dr D. R. P. MURRAY	Permeability of insect cuticle; enzyme systems of insects.
	Dr A. B. P. PAGE, R. E. BLACKWITH and Miss A. PAGE	Insecticidal sprays and films.
	Imperial College Field Station, London Road, Slough, Bucks. Dr O. F. LUBATTI, B. S. GORRINGE, J. RUSSELL, Dr A. B. P. PAGE, Dr G. FRAENKEL	Determination of mercury used for treatment of seed; chemical investugation of fumigation of dried fruit with methyl bromide; chemical study of fumigation of various dried foods with various fumigants; fumigation of onion seed and potatoes for the control of eelworms; nutrition of insects.
Geology	*Department of Geology including Geology and Oil Technology* Professor H. H. READ, F.R.S.	Palaeontology: with special reference to micropalaeontology, foraminifera and algae. Stratigraphy and structural geology: tectonics of dalradian, N. Wales lower palaeozoic, carboniferous limestone of N. of England; Rift Valley tectonics of East Africa. Petrology: granites, granitization and migratization in Cornwall, Eire, Sutherland. Malverns: contaminated gabbros of Scotland. Economic geology: ore deposits of Cornwall; copper deposits Rio Tinto; many problems in water-supply. Oil technology: physics of the migration and accumulation of petroleum; resistivity of fluid-charged sands.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Mathematics	*Department of Mathematics and Mechanics* Professor H. LEVY	Work of theoretical nature (only material available to visitors apparatus for computing and Statistical Section) with experiments to illustrate statistical principles.
Metallurgy	*Department of Metallurgy* Professor C. W. DANNATT Dr M. S. FISHER	Wire ropes research ; erosion of gun barrels and of steel driving bands of projectiles ; effects of stress upon the magnetic properties of steel wire ; the metallography of commercial aluminium alloys.
Mining	*Department of Mining, and (Safety in Mines Research Board)* Professor J. A. S. RITSON E. J. PRYOR Col. J. S. SHEPPARD Mr J. IVOR GRAHAM (*British Colliery Owners Research*)	Wire ropes ; support for roofs in coal mines ; control of roofs in coal mines. The control of fine grindings by wet methods and by dry methods. The application of aerial photography to mine surveying. The elimination of coal dust in mines.
Physics	*Department of Physics* Sir GEORGE THOMSON, F.R.S.	Nuclear physics ; electron diffraction ; technical optics (including colour vision) ; spectroscopy.

2. IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Plant Physiology	*Plant Physiology Institute* Professor F. G. GREGORY, F.R.S. and others	The effects of minor elements in the nutrition of plants; problems of propagation in various species of fruit, especially the part played by plant hormones in the growth of cuttings; various methods of applying synthetic hormones before planting out (in conjunction with East Malling Research Station). Carbohydrate metabolism of the ear of cereal plants; study of the precursor of starch stored in the grain and the biochemical mechanism concerned; the effects of day-length and temperature in controlling bulbing and flower production in the onion plant (in conjunction with Rothamsted Experimental Station). Vernalization of rye, the reversibility of the low temperature effect by subsequent exposure to high temperature (in conjunction with Chelsea Physic Garden).
Zoology	*Department of Zoology and Applied Entomology* Professor J. W. MUNRO Dr R. DENNELL Dr R. DENNELL H. R. HEWER H. R. HEWER and Miss RADLEY	Physico-chemical properties and morphological structure of arthropod cuticles. Stomato-gastric nervous system of *Sergestes*. Analysis of variations in nature of populations of *Zygaena* (Lepidoptera). Accurate determination of colour pigments in insect wings.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
	Department of Anatomy	
Anatomy	Professor T. NICOL	The effect of hormones on the female reproductive system.
	Biochemistry Laboratory	
Biochemistry	Dr W. ROBSON	The amino acids of proteins and their fate in the animal organism.
	Department of Botany	
Botany	Professor T. A. BENNET-CLARK and Sir NIGEL BALL	Growth reactions of diageotropic storage organs.
	Professor T. A. BENNET-CLARK	Effect of auxins on water uptake and osmotic relations of plant tissue slices ; effects of carbon dioxide supply on growth and acid production by mould fungi.
	Dr C. G. DOBBS	Studies in the mucorales.
	Dr J. CARPENTER	Polygenic selection in *Drosophila melanogaster*.
	Department of Chemistry	
Chemistry	Professor A. J. ALLMAND, F.R.S.	Structure of electrodeposited alloys.
	Professor D. H. HEY	Reactions of free atoms and radicals in solution ; mechanism of addition polymerization ; synthesis of new chemotherapeutic agents ; synthesis of compounds possessing sex hormone activity.
	Dr GWYN WILLIAMS	Kinetics of addition polymerization ; mechanism of aromatic nitration.
	J. C. D. BRAND	Mechanism of aromatic sulphonation.
	Dr J. HONEYMAN	Reactions in the carbohydrate series.
	Dr D. W. G. STYLE	Kinetics of oxidation processes.
	Dr F. C. TOMPKINS	Kinetics of solid phase decompositions.
	Dr V. GOLD	Kinetics of reactions in solution.

3. KING'S COLLEGE (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Engineering **(i) Civil Engineering**	*Department of Civil and Mechanical Engineering* Professor C. H. LOBBAN	Development of moment distribution methods ; influence of the joints on the stress distribution in framed structures.
	Professor S. J. DAVIES Dr A. D. ROSS	Investigation of some aspects of gas turbines ; steam flow through nozzles. Studies in reinforced concrete ; effects of creep and shrinkage on stress distribution, deflection and design of structures ; the mechanics of instability as affected by creep.
	Dr L. A. BEAUFOY	A method of analysis of continuous structures with curved members of varying moments of inertia.
	Dr H. E. ROSE	Study of particle size by photo-electric methods.
(ii) Electrical Engineering	*Department of Electrical Engineering* Professor J. GREIG (*Siemens' Engineering Laboratory*)	Investigation of the accuracy of the Owen A.C. Bridge when employed for the measurement of iron losses at audio-frequency under conditions involving appreciable distortion ; investigation of the 'build-up' of oscillations in the R.C. type oscillator and of the factors determining the amplitude of oscillation.
	Dr B. C. LEE	Predetermination of electro-magnetic forces between the coils of transformer windings, utilizing measurements of rate of change of mutual inductance of model systems ; the behaviour of solid iron under suddenly applied constant magneto motive force.
Geography	*Department of Geography* Dr H. J. WOOD E. D. SMETHAM Professor W. T. GORDON W. G. V. BALCHIN	Geographical problems in the western United States. Geography of the area round Sittingbourne and Milton Regis, Kent. The geographical development of the Isle of Sheppey and the Swale. Micro-climates.
Geology	*Department of Geology* Professor W. T. GORDON Dr A. K. WELLS J. F. KIRKALDY	The Lower Caroniferous flora of the volcanic ash bands at North Berwick. The provenance of the coarser material of the Lower Greensands of Surrey. The sedimentary petrography of the Lower Cretaceous rocks of the Weald with special reference to the tracing of minor lithological subdivisions.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Mathematics	*Department of Mathematics* Dr E. T. DAVIES Dr G. C. MCVITTIE and T. V. DAVIES Professor J. G. SEMPLE Professor G. TEMPLE, F.R.S. J. TODD Dr V. C. A. FERRARO	 Differential geometry and calculus of variations. Hydrodynamics, meteorology and stellar structure. Algebraic geometry. Aerodynamics and gas dynamics. Modern algebra. Geo-magnetism.
Pharmacology	*Pharmacology Laboratory* Dr D. B. TAYLOR	 Theory and practice of protein and enzyme purification.
Physics	*Wheatstone Laboratory* Dr F. C. CHAMPION Dr F. W. CHAPMAN Dr S. G. TOMLIN Dr L. PINCHERLE	 Cloud chamber work on the Neutrino ; measurement of the scattering of fast electrons by nuclei at large angles by a combined chamber and counter arrangement ; behaviour of geiger-counters filled with very heavy vapours ; the absorption and scattering of neutrons by various elements. Investigations into electrical disturbances due to thundercloud discharges, using cathode ray oscillographs ; examination of the electrical properties of matter, using electro-magnetic waves of 1 cm. wavelength. Experiments with a new type of ionization chamber. Refraction of non-uniform electro-magnetic waves at the boundary between two absorbing dielectrics ; scattering of nucleons by light nuclei.
Physiology	*Department of Physiology* Professor R. J. S. MCDOWALL	 Investigations into the control of the circulation of the blood, with special reference to the action of hormones.
Zoology	*Department of Zoology* Professor D. L. MACKINNON	 Protozoology.

4. London University Schools of Medicine

(a) Bethlem Royal Hospital

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Biochemistry and Biophysics	*The Wakefield Laboratories* Dr C. Lovell	Microchemical investigations of toxaemias ; the influence of charged films on cell metabolism.

(b) British Postgraduate Medical School

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Gynaecology	*Department of Obstetrics and Gynaecology* Professor J. Young Professor R. J. Kellar	Toxaemias of pregnancy ; pyelitis of pregnancy.
Medicine	*Department of Medicine* Dr McMichael Professor O. G. Edholm Dr S. Sherlock Dr E. G. L. Bywaters	Cardiac output ; peripheral bloodflow in various forms of circulatory failure ; study of liver disease by biopsy methods ; kidney functions in trauma ; lung volume studies in disease.
Pathology	*Department of Pathology* Professor J. H. Dibble Lord Stamp Professor E. J. King Dr I. Doniach Dr M. Meyrick	Peripheral vascular supply in gangrene of the extremities. Preservation of bacteria by drying. Pneumokoniosis and purification of phosphatose. Pathological changes in uraemia. Antibacterial action of derivatives of aminophenol ; cytological changes in the endometrial stroma ; cytology of bone marrow and the anaemias ; metabolism of porphyrons.
Surgery	*Department of Surgery* D. M. Douglas	Experimental incisional hernia.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
	Royal Cancer Hospital	
Cancer Research	Dr ERIC BOYLAND	Metabolism of anthracene ; chemotherapy of cancer.
	Dr PIERRE DUSTIN	Cytological effects of urethane ; mitotic effects of colchicine, arsenic and trypaflavine ; vacuolation of reticulocytes by basic substances.
	Dr L. A. ELSON	Metabolism of carcinogenic azo substances and aminostilbenes.
	Dr ALEXANDER HADDOW	Chemotherapy of leukaemia ; carcinogenic aminostilbenes ; radioactive phosphorus in relation to neoplasms ; artificial induction of hair pigmentation in rats.
	Dr R. J. C. HARRIS	Metabolism of nucleoproteins.
	Dr I. HIEGER and Dr C. W. SHOPPEE	Carcinogenic extracts of human tissues.
	Dr CORNELIA HOCH-LIGETI	Conditions affecting carcinogenic action in the liver.
	Professor E. L. KENNAWAY, F.R.S., and Mrs N. M. KENNAWAY	Statistics of cancer of the lung, larynx, bladder and prostate in England and Wales.
	Professor K. F. GOULDEN and D. M. BROWN	Synthesis of carcinogens ; growth-inhibitory compounds in relation to chemotherapy.
	Professor E. L. KENNAWAY, F.R.S., and Miss TIPLER	Metabolism of ascorbic acid.
	Dr EDNA ROE	Ultraviolet spectroscopy of biologically important substances.
	Dr F. L. WARREN and Miss E. RHODEN	Chemical estimation of urinary steroids.

(d) GUY'S HOSPITAL MEDICAL SCHOOL

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry	*Chemistry Department* Professor C. S. GIBSON Dr F. H. BRAIN Dr R. V. G. EWENS	The investigation of complex organic and inorganic compounds of the metals of Groups I and VIII.
Clinical Medicine	*M.R.C. Clinical Research Unit* Dr R. T. GRANT	Clinical and experimental observations relating particularly to the cardio-vascular system.
Pathology	*Pathology Department* Professor G. PAYLING WRIGHT Dr S. J. HOPKINS Dr H. WYATT Dr S. J. DE NAVASQUEZ Dr P. A. I. GORER Professor G. PAYLING WRIGHT Dr N. AMBACHE	Toxicology of clostridial toxins. Experimental production of arteritis. Genetics and transmission of leukaemia. Vital statistics of infectious diseases of infants. Study of pharmacology and electrophysiology of neuro-muscular transmission in smooth muscle.
Pharmacology	*Bacteriological Department* Dr F. A. KNOTT	Inhalation treatment with penicillin and use of penicillin mists against cross infection.
Physics	*Physics Department* Professor G. STEAD Dr C. B. ALLSOPP	The mechanism of chemical carcinogenesis.
Physiology	*Physiology Department* Dr G. A. D. HASLEWOOD Dr E. O. HOHN Dr P. M. F. BISHOP	Pregnandiol estimations. Endocrine cycles in birds by histological methods. Human endocrinology.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Bacteriology	Dr H. SCHÜTZE Dr E. KLIENEBERGER-NOBEL Dr R. ST JOHN BROOKS and Dr M. RHODES	Bacterial immunity. Nuclear structures in bacteria. National collection of type cultures.
Bacterial Chemistry	Sir PAUL FILDES, F.R.S., and others	
Bacterial Vaccines	Dr A. F. B. STANDFAST Dr H. H. EAGLES and Dr C. H. LACK	The preparation of bacterial vaccines. The preparation of vaccine lymph.
Biochemistry	Dr W. T. J. MORGAN, Dr M. G. MACFARLANE and Dr K. A. SMITH Dr H. J. ROGERS Dr W. T. J. MORGAN, Dr M. B. R. WADDELL and Dr H. LAURELL Dr R. L. M. SYNGE Dr D. ELLINGER, Dr E. EMANUELOV and Dr ABDEL KADER	Immunochemistry of bacterial antigens and toxins. Constitution of hyaluronic acid. Immunochemistry of blood group substances. Chemistry of proteins. Nicotinamide metabolism and deficiencies ; fluorimetry.
Biophysics	Dr. R. A. KEKWICK and Dr B. R. RECORD Dr C. BRADISH Dr B. CINADER	Fractionation of plasma. Freeze-drying and ultrasonics. Tetanus toxin and antitoxin.
Experimental Pathology	Dr A. N. DRURY, Dr S. J. L. SPOONER and Dr W. D'A. MAYCOCK	Cardiac hypertrophy ; muscle ischaemia.

(e) LISTER INSTITUTE OF PREVENTIVE MEDICINE (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Nutrition	Dr E. M. HUME, Dr A. M. COPPING and Dr V. R. G. POND Dr S. S. ZILVA, J. R. PENNY and H. PAINTER	Studies of Vitamin A and Vitamin B complex. Biochemical problems in Vitamin C metabolism.
Physiology	Dr E. F. MCCARTHY	Osmotic pressure studies of haemoglobin and serum proteins.
Protozoology	Dr M. ROBERTSON	Researches on trichomonas features.
Serum Unit	Dr E. S. DUTHIE, Dr J. KEPPIE and Dr M. STACK Dr M. M. MACKAY, Dr E. RICHARDSON and Dr M. JONES	Various topics in the production of antisera. Fractionation of plasma.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	Professor M. F. LUCAS KEENE and Dr (Miss) E. HEWER Dr (Miss) L. M. DICKSON (under the direction of Sir JOSEPH BARCROFT, F.R.S.) Dr (Miss) R. E. M. BOWDEN (under the direction of Professor H. J. SEDDON)	Structural development of the human embryo with particular relation to the parathyroid glands and biliary ducts. The development of nerve endings in the respiratory muscles of sheep; comparative date of maturation of nerve endings in voluntary muscles of certain laboratory animals; possible causes of repeated occurrence of anencephaly after the birth of the normal child. Changes in human voluntary muscle on denervation and re-innervation.
Biology	Miss C. L. T. LUCAS Mrs G. M. MILLS Mrs A. M. HUGHES	Reproductive mechanism of the earthworm *Lumbricus herculeus* (*terrestris*). The pedal gland of certain Gasteropod mulluscs and its functions. Mites associated with stored food products.
Chemistry	Dr A. LAWSON	Preparation and action of antithyroid drugs (at University College Medical School).
Physics	Dr (Miss) LEYSHON and Miss M. E. J. CARR	Dielectric constants of fluids at centimetre wave-lengths.
Physiology	Professor M. F. LUCAS KEENE and Miss M. BOND Miss A. SHOVE Mrs P. P. SCOTT	Effect of diet on the development of myelinated nerve fibres. Chemistry of proteins. The effects of tryptophane deficiency on the development and function of the nervous system in laboratory animals.

(g) LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Bacteriology	*Department of Bacteriology* Professor G. S. WILSON	Studies on the rabies virus ; the bacteriophage typing of animal strains of staphylococci.
Biochemistry	*Biochemistry Department* Professor H. RAISTRICK, F.R.S.	Metabolism of micro-organisms, particularly the lower fungi, and production and characterization of antibiotics.
Entomology	*Entomology Department* Professor P. A. BUXTON, F.R.S.	Acclimatization of insects to changes of temperature.
(i) Medical Entomology **(ii) Insect Physiology and Behaviour**		Systematics of mosquitoes from the Middle East ; insecticides ; the oviposition of mosquitoes ; climate and insect metabolism ; effects of climate on mosquito feeding reactions ; control of activity of mosquitoes.
Medical Statistics	*Department of Medical Statistics* Professor A. BRADFORD HILL	Problems of industrial health in conjunction with the M.R.C.'s Industrial Health Research Board ; medical problems of flying personnel in conjunction with the Royal Air Force ; statistical studies of mortality and morbidity ; statistical methodology in biological assay, bacteriology and other medical sciences.
Parasitology	*Department of Parasitology* Professor R. T. LEIPER, F.R.S.	*Plasmodium gallinaceum*—study of stages in the incubation period after bites of mosquitoes ; *Plasmodium cynomolgi*—study of stages in incubation period after bites of mosquitoes.
(i) Protozoology	Colonel H. E. SHORTT	Leishmania—comparative study of the recognized species. Toxoplasma—development in the animal body. Maintenance of strains of various protozoa, and of mosquitoes, *Anopheles* and *Aedes*.
(ii) Helminthology	Professor R. T. Leiper, F.R.S.	Life histories of helminths of medical interest ; maintenance of molluscan intermediaries ; tests for anthelmintic potency ; taxonomy of helminths in tropical fauna.

(g) LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Physiology	*Department of Applied Physiology* Professor G. P. CROWDEN	Influence of radiation, ventilation and humidity on thermal comfort in living rooms of working-class houses; air-conditioning for the Tropics with special reference to the effects of radiation on thermal comfort.
	Dr T. C. ANGUS	Dust estimation and control in industry.

(h) MAUDSLEY HOSPITAL MEDICAL SCHOOL

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Electro-Physiology	Dr D. HILL	Electro encephalography in mental disorders.
Neuro-anatomy	Dr A. MEYER	Problems of prefrontal leucotomy; cerebral anoxia; structure of synapses.
Psychiatry	Professor A. J. LEWIS	Social surveys and selection.
	Dr E. GUTTMANN Dr E. SLATER	Inheritance of mental disorder.
Psychology	Dr H. J. EYSENCK Dr H. HIMMELWEIT Dr A. PETRIE Miss H. GOLDSCHMIDT	Measurement of dimensions of personality. Objective psychological measurements in normal and maladjusted children in relation to the social background.

(i) MIDDLESEX HOSPITAL MEDICAL SCHOOL

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Biochemistry	*Courtauld Institute of Biochemistry* Professor E. C. DODDS, F.R.S. W. LAWSON Dr WILDER-SMITH Dr F. DICKENS, F.R.S. Dr J. A. V. BUTLER P. C. WILLIAMS Dr A. C. BOTTOMLEY Dr J. D. ROBERTSON	Synthesis of oestrogens ; mode of action and metabolism of synthetic oestrogenic substances ; methods of chemical determination. Tissue metabolism in relation to cancer. Structure of biologically active protein with particular reference to insulin. Endocrinology with special reference to the pituitary. Constitution of the active principle of anti-anaemic factor in liver extract. Clinical biochemistry with special reference to basal metabolism.
Biology	*Biology Department* Dr J. H. WOODGER Dr C. L. FOSTER	Theoretical biology. Cytology of parathyroid and pituitary glands.
Pathology	*Bland-Sutton Institute of Pathology* Professor J. MCINTOSH	Cancer-virus tumours ; action and application of penicillin, sulphonamides, acridines, etc. ; morbid anatomy and histology with special reference to cancer ; registry of tumours on behalf of British Empire Cancer Campaign ; obscure anaemias ; leukaemia ; RH Factor.
Pharmacology	*Pharmacology Department* Dr C. A. KEELE	Sensitization of animals to certain drugs and study of antigens formed in the tissues—especially arsphenamine and 2/4 dinitrochlorobenzene.
Physiology	*Physiology Department* Professor SAMSON WRIGHT W. F. FLOYD Dr D. SLOME	Action of drugs on central and peripheral nervous systems, particularly potassium and ammonium compounds ; mechanism of transmission of nervous impulse in the spinal cord. Electrophysiological studies on the earthworm ; action of drugs on body wall muscles. Effect of drugs on action of phosphatase by histochemical methods.
Radiotherapy	Professor S. RUSS Dr J. E. ROBERTS Miss G. M. SCOTT	Effects of extra Vitamin B complex feeding on rats exposed to continuous weak gamma radiation ; increased resistance to sarcoma by use of cell-free extracts of sarcoma ; physical problems of radiotherapy.

(j) PHARMACEUTICAL SOCIETY, COLLEGE OF THE

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Pharmaceutics	Professor H. BERRY Professor W. H. LINNELL Professor G. A. H. BUTTLE Dr M. VOGT Dr K. H. COWARD Dr T. E. WALLIS	Measurement of rates of kill of bactericides. Syntheses of new chemotherapeutic agents ; synthetic sex hormones. Biological standardization of drugs. The conditions governing the output of hormone from the suprarenal cortex. Biological standardization of vitamins. Microscopical and histological investigations of crude drugs.

(k) ST MARY'S HOSPITAL MEDICAL SCHOOL

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	*Department of Anatomy*	The factors stimulating bone production in normal growth and in the repair of injuries ; comparative morphology of the fore-brain in primitive mammals.
Chemistry	*Department of Chemistry*	Autoxidation products of fatty acids ; derivatives of the *epoxy* compounds of oleic and of elaidic acid.
Physics	*Department of Physics*	Study of weak radioactivities with a Wilson Expansion Chamber.
Physiology	*Department of Physiology*	Acceleration due to gravity and the distribution of blood in the body ; fat metabolism with particular reference to the colloidal particles of fat in blood ; pre-natal development and nutrition.

(l) ST THOMAS'S HOSPITAL MEDICAL SCHOOL

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	*Department of Anatomy* Professor A. B. APPLETON Dr R. WHEELER HAINES Dr H. HUGHES	Relation of posture to the centre of gravity ; the bronchi and blood vessels of the lungs. The mechanism of respiration ; the mechanism of ' snapping ' of joints. The origin and regeneration of the islets of Langerhans ; the post-natal growth of tendons.
Pathology	*Department of Pathology* Professor W. G. BARNARD Dr T. DAY Dr ROLAND JOHN Dr G. POPJAK Dr J. PINNIGER *William Dunn Laboratory* Dr F. T. G. PRUNTY Dr W. J. GRIFFITHS	General examination of the nature of fibrous tissue and interfibrillary materials. Artificial production of metastases in rat carcinoma. Histological and chemical investigation of ' cloudy swelling.' Clinical and haematological investigation of leukaemia. Biochemical aspects of adrenal virilism. Metabolic problems with particular reference to liver function and the action of insulin.
hysiology	*Sherrington School of Physiology* Professor B. A. MCSWINEY, F.R.S. Dr C. C. N. VASS Dr C. B. B. DOWNMAN Miss J. G. EMMETT	Visceral afferent pathways. Visceral sensitivity and visceral afferent pathways. Visceromotor reflexes. Influence of hormones on gastric secretion.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anaesthetics	Dr C. LUCAS	The affects of anoxia on the brain of rats.
Chemical Pathology	Professor C. RIMINGTON	Synthesis and pharmacological examination of substances having anti-thyroid activity ; purification and chemical characterization of a material isolated from spleen and secreted by this organ in the intact animal as a result of trauma ; purification of the allergens present in crude house dust ; porphyrin metabolism of animals in deficient diets ; the interaction between chemical carcinogens, tissue enzymes and sub-hydra groups ; carcinogenicity of certain pure chemical substances ; isolation and examination of glycoproteins from normal horse serum.
Clinical Pathology	Dr M. MAIZELS	Empirical tests for liver function.
Dermatology	Dr W. FREUDENTHAL	Research in cutaneous histology.
Morbid Anatomy	*Department of Morbid Anatomy* Professor G. R. CAMERON, F.R.S., and Dr JUDAH Professor G. R. CAMERON, F.R.S., and Dr CHENG Dr CHENG Dr DENZ Dr SHORT Dr SHORT and Dr CHENG	The absorption, excretion and detoxification of D.D.T. in the body. The behaviour of plasma proteins in experimental liver disease. Cardiac hypertrophy. The pathology of lymph nodes, with special reference to lymphoid tumours. Factors concerned in thrombosis of peripheral veins ; the finer structure of the lung and its relation to pulmonary oedema. Experimental study of vascular necrosis.

(m) UNIVERSITY COLLEGE HOSPITAL MEDICAL SCHOOL (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Morbid Anatomy (*continued*)	*Department of Morbid Anatomy*	
	Professor G. R. CAMERON, F.R.S.	Regeneration of adipose tissue.
	Dr GLYNN and Professor HIMSWORTH	Mechanism of nutritional and toxic liver injury.
	Dr BENESCH and Dr GLYNN	The distribution of lipase determined hystochemically and its inhibition by specific chemical inhibitors.
	Dr GLYNN and Dr MAIZELS	The effect of enzyme inhibitors on the development of the frog's egg.
	Dr BENESCH and Dr GLYNN	The staining of supphydryl groups and their specific inhibition ; the staining of alkaline phosphatase and its inhibition.
	Dr ELKELES and Dr GLYNN	Experimental encephalitis with special reference to the blood brain barrier.
	Medical Unit	
	Professor H. P. HIMSWORTH	Influence of dirt upon liver disease.
	Dr M. E. MORGANS	Treatment of thyrotoxicosis with thiouracil and allied drugs.
	Dr C. E. DENT	Amino-acid metabolism in relation to liver disease.
Obstetrics	Professor F. J. BROWNE	Reactions to pressor substances in pregnant women.
Radiotherapy	Dr OWEN HILTON and S. OSBORN	Distribution of radiation in the treatment of rodent ulcers of the spectacle region by *beta*, *gamma* and X-rays with special reference to the possibility of damage to the eye.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Biochemistry	*Biochemical Laboratory* Dr N. F. MACLAGAN	Liver function in non-hepatic disease ; differential diagnosis of jaundice ; estimation of faecal urobilinogen ; flocculation tests and preparation of colloidal gold solutions ; blood urea estimation ; urinary hormones in cases of testicular tumour ; faecal urobilinogen in malignant disease ; faecal urobilinogen after bone fractures and its relation to traumatic anaemia ; serum phosphatase in cases of bone tumour.
Haematology	Dr HUMBLE	Size of red cells in relation to fragility ; chloroma ; cytochrome structures of leucocytes ; effect of irradiation on haemoglobin metabolism ; effect of X-rays and radium on human bone marrow ; clinical uses of heparin.
Pathology	*Pathology Department* Dr R. J. V. PULVERTAFT Dr P. KERLEY Dr A. MORGAN	Action of various drugs on the water flea ; plant pollens in the study of antiseptics ; Liesegang rings ; treatment of bronchitis and sinusitis by inhalation of penicillin. Mass radiography of the lung. Radium-sensitivity of tumours.
Physics	*Physics Department* Dr C. W. WILSON J. R. GREENING Miss S. M. ALY and others	Valve amplifier for measurement of gamma-ray dose ; electrical counting apparatus for use with Geiger-Müller counters ; scattered radiations in media irradiated with high voltage X and *gamma* rays ; effect of X-rays on rabbit brain, and on brain tumours of mouse.
Radiotherapy	*Radiotherapy Department* Dr F. M. ALLCHIN Sir STANFORD CADE	Clinical studies of neoplastic disease, particularly carcinoma of breast and larynx, seminoma and lymphadenoma.

5. London University—Polytechnics

(a) Battersea Polytechnic

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry **(i) Organic** **(ii) Physical**	*Chemistry Department* Dr J. Kenyon, F.R.S.	Study of organisms by use of optically active compounds ; conductivities of various types of electrolytes in non-aqueous solutions ; dipole moments of alcohols ; dissociation and hydrolytic constants of some bivalent metallic salts.
Mechanical and Civil Engineering	*Mechanical and Civil Engineering Department* S. A. Robertson	Various investigations, including water-tube boilers, hydraulic ram, bearing reactions on foundations with concentric and eccentric loads.
Physics	*Physics Department* Dr Marsh Dr Symons Dr Heath	Discharge of electricity in high vacua ; anode phenomena ; fluorescence ; spectroscopic studies.

(b) Chelsea Polytechnic

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Biology	Dr B. Barnes C. J. A. Berkeley	Structure and reproduction of algae. Digitalis purpura.
Geology	N. E. Pettitt M. D. S. Lewis	Chalk Rhynchonallacea. Surface properties of gem-stones.
Physics	Dr W. H. George C. G. Cameron	Coefficient of restitution of coals.

(c) NORTHERN POLYTECHNIC

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry		
(i) Organic	Dr R. W. WEST Dr W. GERRARD	Strengths of linkages in derivatives of ethyl malonate. Mechanism of interaction of hydroxy-compounds with thionyl and phosphorus halides ; and with carbonyl chloride.
	Dr W. J. BARRY Dr R. W. WEST	Reduction of thionaphtheno-pyrazoles. Rubber—the action of accelerators ; semi-ebonite ; mechanism of reaction of phenol and formaldehyde.
(ii) Inorganic	Dr H. J. S. KING	Co-ordination compounds ; platinum ammines.
(iii) Physical	Dr R. BUCKINGHAM Dr E. G. COWLEY	Polymerization ; rubber sols. Dipole moments.
Physics	Dr A. E. BATE	Thixotropy ; velocity of sound in tubes at normal and low temperatures.

(d) WOOLWICH POLYTECHNIC

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry	*Department of Chemistry* Dr A. I. VOGEL	Measurements of refractive indices, densities and surface tensions of pure organic compounds leading to calculations of molecular refractivities, parachors, etc.
Physics	*Department of Physics* Dr D. H. SMITH	Velocity of sound in gases by tube methods.

6. Queen Mary College

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Zoology	*Zoology Department* Dr A. J. Grove	Tube-building in tubicolous Polychaetes ; the skeletal effects of body fluids in soft bodied invertebrates ; structure and innervation of the ascidian heart.

7. Royal Holloway College

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany		Water inhabiting Phytophthora ; causeo f cork formation in the potato ; haustoria.
Chemistry **(i) Inorganic** **(ii) Organic**	Dr A. G. Foster Dr M. M. T. Plant and Miss J. W. E. Brading	New methods of volumetric analysis. Extraction, purification and methylation of algal polysaccharidic material ; fractionation of methylated sugar mixtures by high vacuum distillation.

8. Sir John Cass Technical Institute

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry	*Department of Chemistry* Dr A. M. Ward Dr A. J. Lindsey Dr S. Dagley A. Lidstone A. Dutton	Analytical chemistry ; precipitated metallic sulphides. Dropping mercury cathode and polarography ; mechanism of electrolytic reduction ; electrolyte diffusion at the mercury cathode ; effect of colloids on electrocapillary maxima. Kinetics of bacterial growth. Co-ordination complexes from triarylboranes ; five co-valent derivatives of arsenic and antimony ; behaviour of additive compounds of enantiomorphs. Studies in Diels-Alder Diene reaction.
Physics	*Department of Physics and Mathematics* R. H. Humphry H. L. Jolley F. J. Hill	Interference in semi-reflecting films. Dielectric hysteresis. Properties of unimolecular surface films.

9. South-Eastern Agricultural College

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Agriculture, Horticulture, Pig Husbandry	*Wye College Farm, Ashford, Kent* N. L. Tinley	Variety trials with Danish barley, forage crops, German ryewheat, potatoes, brussel sprouts, etc. ; vernalization of tomatoes ; parthenocarpic-inducing substances ; breeding and cultivation of hops ; wound hormones and phytotoxicity ; persistence of D.D.T. and hexachloro-cyclohexane in soil ; new insecticides ; influence of environment on breeding of gilts.

10. University College

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Biometry	*Department of Biometry* **Professor J. B. S. Haldane, F.R.S.**	Genetics of man, mouse, Drosophila, Culex and some Urodeles with special reference to mental abnormality in men and physiological abnormality in mice.
Botany	*Department of Botany* **Professor W. H. Pearsall, F.R.S.**	Nitrogen metabolism in plants ; nitrogen fixation by algae ; nitrogen transformation by soil fungi ; nitrogen metabolism of leaves ; British freshwater algae—particularly flagellates and phytoplankton ; surface properties of leaf cuticle ; timber structure in relation to taxonomy and utilization ; algal growth in pure culture ; biological relations of oxidation-reduction potentials in culture media and soils ; ecology of forest and water-logged soils.
Chemistry	*Chemistry Department* **Professor C. K. Ingold, F.R.S.**	Near-ultraviolet transition of benzene ; deuterium substitution products ; halogen substitution products ; Raman spectra of solutions containing NO_2^+ ion and of phosphorus pentahalides ; forms assumed by oxides of nitrogen in solution in nitric and sulphuric acid by cryoscopic, conductomeric and optical methods ; kinetics and mechanism of aromatic nitration ; kinetics and mechanism of aliphatic substitution, including unimolecular reactions in sulphur dioxide, and quantitative evaluation of steric hindrance in bimolecular reactions ; hydrolysis mechanisms by use of heavy-oxygen enriched water ; ionic equilibria in long chain polyenes; magnetic properties of compounds of the rare earth metals.
Chemical Engineering	*Department of Chemical Engineering* **Professor H. E. Watson**	The design of stills and packings for the separation of closely boiling liquids such as the isotopic varieties of water ; mechanism of flooding.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Geology	*Department of Geology* Dr L. J. CHUBB	Electrodialysis of mineral silicates ; rock weathering ; the structure nomenclature, variation and evolution of Liassic Foraminifera with a view to zoning the Lias by Foraminifera ; the igneous complex of Skye.
Physics	*Physics Department* Professor E. N. DA C. ANDRADE, F.R.S.	Investigations on various aspects of the viscosity of liquids ; preparation and properties of metal single crystals ; vacuum spectroscopy in the region 10 to 200A.
Physiology	*Department of Physiology* Professor C. A. LOVATT EVANS, F.R.S.	Acetic acid and lower ketone bodies in the human body ; effects of alcohol on diuresis.
Zoology	*Department of Zoology* Professor D. M. S. WATSON, F.R.S.	Nuclear cytology of cecidomiids ; general physiology of polychaete worms ; the grey lethal gene in mice ; palaeontology of amphibia and reptiles.

11. WESTFIELD COLLEGE

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botany Department* Dr E. M. DELF	Structural features of species of Fucus in relation to environmental and genetic factors; reproductive mechanisms in Fucales with special reference to the Australian genera Scytothalia and Turbinaria; movement of certain ions through plant tissues.
Palaeobotany	Dr M. G. CALDER	A Patagonian fossil flora of (?) Cretaceous age, with special reference to Coniferalean types; a terrestrial species of Rhodochorton from Kincardineshire, Scotland.

12. WEST HAM MUNICIPAL COLLEGE

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry	Dr E. A. RUDGE and others	Organo-metalic compounds of titanium; precipitation phenomena with humic acid solutions.
	Dr F. L. ALLEN and others	Heat of hydration of cellulose; fluorine derivatives of pyridine; fluorine derivatives of condensed ring systems; fluorine derivatives of heterocyclic compounds.
	Dr W. R. BURNHAM and others	Potentials of bismuth and arsenic electrodes; kinetics of catalytic oxidation of sulphur dioxide; transport number measurements.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry **(i) Physical**	*Department of Physical Chemistry* Professor M. POLYANI, F.R.S.	Polymerization of unsaturated hydrocarbons; measurement of bond energies; studies in the inorganic and physical chemistry of the catalytic halides.
(ii) Organic	*Department of Organic Chemistry* Professor E. L. HIRST, F.R.S.	The fine structure of polysaccharides and alkaloids; calorimetry.
Bacteriology and Preventive Medicine	*University of Manchester Public Health Laboratory* Professor H. B. MAITLAND	
Electro-Technics	*Electro-Technics Department* Professor WILLIS JACKSON	Measurement of the electrical properties of dielectrics over the frequency range 10^4—10^{10} c/s; the electric strength of air and other gases at frequencies of the order of 10^{10} c/s; measurements of the intrinsic electric strength of crystalline and amorphous dielectrics; various studies in electronics and electron optics.
Engineering	*Engineering Department* Professor A. H. GIBSON	Hydraulic models.
Physics	*Physical Laboratories* Professor P. M. S. BLACKETT, F.R.S. Dr S. TOLANSKY	Cosmic rays. Interferometry; high resolution spectroscopy.

XII. UNIVERSITY OF OXFORD

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Agriculture	*Institute for Research in Agricultural Economics* A. W. ASHBY R. N. DIXON J. R. RAEBURN R. S. G. RUTHERFORD	Economics of land and agriculture ; agricultural production and farm management ; marketing and co-operation ; supplies and prices ; rural social organization.
	School of Rural Economy C. G. T. MORISON	Soil science.
Anatomy	*Department of Anatomy* Professor W. E. LE GROS CLARK, F.R.S. Dr G. A. M. WEDDELL Dr A. B. CARLETON Dr R. C. HARRISON Dr R. BARER Dr H. S. WAJDA	Electro-myography ; cutaneous sensation ; physiological effects of climate ; muscle regeneration ; the adrenal cortex.
	J. S. WEINER	Physical anthropology.
Astronomy	*University Observatory* Professor H. H. PLASKETT, F.R.S.	Solar investigation.
Biochemistry	*Biochemical Laboratory* Professor R. A. PETERS, F.R.S. C. W. CARTER Dr R. B. FISHER Dr R. H. S. THOMPSON Dr A. G. OGSTON J. R. P. O'BRIEN Dr L. A. STICKEN Dr D. D. WOODS	Biochemistry of thermal and lewisite burns ; vitamin B complex and anaemia ; metabolism of porphyrins ; vitamin C nutrition ; ultra-centrifuge and proteins ; microbiochemistry.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botanical Department* Professor T. OSBORN Dr W. H. WILKINS Dr W. O. JAMES Dr N. POLUNIN Dr J. L. HARLEY Dr J. F. HOPE-SIMPSON R. SNOW	Plant ecology : production of bacterio-static substances by fungi ; plant respiration ; alkaloid metabolism of plants ; the flora of the Canadian Arctic ; beech mycorrhiza ; grassland ecology ; soils and vegetation of the drier tropics ; phyllotaxy-auxins.
Chemistry **(i) Organic**	*Dyson Perrins Laboratory* Professor Sir ROBERT ROBINSON, P.R.S. Dr S. G. P. PLANT Dr E. HOPE Dr T. W. J. TAYLOR Dr J. C. SMITH Dr F. E. KING Dr W. A. WATERS Dr and Mrs CORNFORTH Dr A. J. BIRCH Dr N. POLGAR Dr J. A. BARLTROP	Structure and synthesis of natural products ; chemotherapy ; chemistry of hydrocarbons ; oestrogenic and carcinogenic substances ; branched chain fatty acids derived from tubercle bacilli ; reduction of aromatic substances ; mechanism of oxidation processes ; metabolism of atebrine ; reactions of organic compounds.
(ii) Physical	*Physical Chemical Laboratory and Inorganic Chemical Laboratory* Professor C. N. HINSHELWOOD, F.R.S. E. J. BOWEN, F.R.S. J. H. WOLFENDEN R. P. BELL, F.R.S. L. E. SUTTON H. W. THOMPSON, F.R.S. L. A. STAVELEY J. D. LAMBERT D. H. EVERETT C. A. COULSON J. W. LINNETT	Reaction kinetics ; physical chemistry of bacterial growth ; fluorescence ; photochemistry ; infra-red spectroscopy ; application of short waves to chemistry ; supersonics ; electro-chemistry ; thermodynamical properties of matter ; properties of dielectrics ; separation of isotopes ; wave-mechanics.

XII. UNIVERSITY OF OXFORD (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemical Crystallography	*University Museum* Dr H. POWELL Mrs D. HODGKIN	Structure of proteins and other organic and inorganic molecules.
Engineering	*Engineering Department* Professor A. THOM	Civil engineering problems
Entomology	*Hope Department* Professor G. D. H. CARPENTER	Life histories, variations, influence of birds on, and control of insects.
Forestry	*Department of Forestry* Professor H. G. CHAMPION	Relations between growth and health of trees and their environment; physical and biological taxonomy of trees and timbers.
Metallography	*Inorganic Chemistry Laboratory* Dr W. HUME-ROTHERY, F.R.S.	Metallography, including high and low temperature X-ray methods.
Nutrition	*Oxford Nutrition Survey* Dr H. M. SINCLAIR	Recent studies of nutritional status in England and on the Continent.
Ornithology	*Edward Grey Memorial Institute for Field Ornithology* Dr ALEXANDER Dr TUCKER D. LACK	Behaviour, distribution, and migration of birds.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Pathology	*Sir William Dunn Laboratory* Professor Sir HOWARD FLOREY, F.R.S. Dr E. CHAIN Dr N. G. HEATLEY Professor A. D. GARDNER Dr L. BERENBLUM Dr A. Q. WELLS	Detection and testing of anti-biotics. Chemistry of anti-biotics. Isolation of anti-biotics. Leptospirosis—serological and pathological investigations. Carcinogenic substances, their metabolism and derivatives. *Mycobacterium muris* (the vole bacillus of Wells) ; immunization of animals and man against tuberculosis.
Pharmacology	*Department of Pharmacology* Professor J. H. BURN, F.R.S. Dr H. R. ING	Biological methods for testing : Substitutes for atropine (i) on the pupil of the mouse, (ii) on the salivary gland of the cat. Substitutes for quinidine on the isolated auricles of the rabbit. New antidotes for curarine on the isolated phrenic nerve—diaphragm of the rat. New analgesic substances. New local anaesthetic substances— (i) on the skin of the guinea-pig, (ii) on the sciatic plexus of the frog. Pharmacological properties of anti-biotic substances—patulin, penicillin acid, penicillin, streptomycin.
	Miss EDITH BULLRING	The relation of adrenaline to acetylcholine in the nervous system, and the phenomena underlying hysterical reactions.
	Dr H. BLASCHKO	Methods of biological standardization. Action of drugs on enzymes present in the liver and kidney.

XII. UNIVERSITY OF OXFORD (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Physics	*Clarendon Laboratory* Professor Lord CHERWELL, F.R.S. Professor F. E. SIMON, F.R.S. Dr G. M. B. DOBSON, F.R.S. T. C. KEELEY Dr D. A. JACKSON H. G. KUHN C. H. COLLIE	Low temperature physics ; application of Cm. waves to physics ; hyperfine structure spectroscopy ; meteorology of the upper air.
Physiology	*Physiological Laboratory* Professor E. G. T. LIDDELL, F.R.S. Dr F. P. GLEES Dr DAVID WHITTERIDGE Dr F. G. C. COURTICE GEORGE GORDON E. H. LEACH Dr C. G. PHILLIPS Dr A. H. HOLBOURN (*physicist*)	Nervous reflex action. Nerve impulses. Electro physiology. Blood gases. Respiration. Histology.
Zoology	*Department of Zoology and Comparative Anatomy* Professor A. C. HARDY, F.R.S. Dr J. R. BAKER *Burean of Animal Population* C. S. ELTON Dr E. B. FORD, F.R.S. Dr W. HOLMES P. B. MEDAWAR H. K. PUSEY	Experimental study of vertical migration of plankton animals ; distribution of insects by wind. Histochemical recognition of tipine. Group research on population dynamics in mammals. Genetical studies in Lepidoptera. Pathology of peripheral nerve injuries. Genetical aspects of immunology. Evolution of frog skull.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	Professor F. DAVIES	The conducting system of the hearts of various vertebrates (cold-blooded and warm-blooded) ; histological and chemical studies.
Biochemistry	Professor H. A. KREBS	Investigations into the intermediary metabolism of animal tissues as studied on isolated material, with special reference to the mode of breakdown of fatty acids and aceto-acetic acid ; investigations into the mechanism of hydrochloric acid production in the stomach as studied on the isolated surviving gastric mucosa ; investigations into bacterial metabolism, especially the mechanism of action of growth factors.
Botany	Professor A. R. CLAPHAM	Microbiology of acid soils ; the nature of the oxidase system in plant cells ; investigation of the behaviour, and especially of the depth-adjustment, of various rhizomes ; studies in peat formation in the Southern Pennine area ; taxonomic studies in Juncus, Thlaspi and Cochlearie.
Chemistry	Professor W. N. HAWORTH, F.R.S.	Investigations on natural products ; constitution of resins, alkaloids, etc. ; kinetic studies of some organic reactions ; problems in analytical chemistry.
Engineering	Professor H. W. SWIFT	The mechanical aspects of plastic flow in metals ; problems connected with deep drawing and similar press operations ; journal and thrust bearing lubrication.
Fuel Technology	Dr W. A. KIRBY	Chemical constitution of coal, particularly in connexion with the form in which nitrogen is present ; combustion characteristics of coals ; semi-micro and micro-chemical methods of analysis of solid fuels and of gases.

XIII. UNIVERSITY OF SHEFFIELD (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Geology	**Professor SHOTTON**	Palaeogeography of the British Permo-Trias rocks ; investigation of the Rossland alkali granite complex of the Lower Arrow Lake, British Columbia ; the metamorphosis of the Tan-y-Grisiau micro-granite, North Wales ; the palaeontology of Jurassic ostracoda ; the stratigraphy of the Purbeckian.
Glass Technology	**Professor MOORE**	Studies of temperature gradients in molten glass ; colour produced by metallic oxides as controlled by oxidation potentials.
Metallurgy	**Professor J. H. ANDREW**	An investigation into the causes of hair-line cracks in steel ; changes in X-ray structure, and in physical and mechanical properties induced in steel by various forms of cold-working ; slag metal reactions, with particular reference to the removal of phosphorus in steel ; diffusion constants of metals measured by spectrographical means ; researches on alloy steels, coil springs, steel castings, viscosity of welding slags.
Mining	**Professor I. C. A. STATHAM**	Mine ventilation ; mine dusts ; the safe use of power in mines ; mining subsidence ; flame propagation in breaks in strata ; coal cleaning.
Pathology	**Professor GREEN**	Shock—the role of adenosine triphosphate and related compounds in shock ; cancer—the mechanism of 2-aminofluorene carcinogenesis ; industrial diseases—pneumokoniosis produced by iron, manganese, graphite, boiler scales, etc.
Pharmacology and Therapeutics	**Professor E. J. WAYNE**	Investigation of Myasthenia Gravis with special reference to causation and treatment ; investigation of hyperthyroidism with special reference to aetiology and treatment with anti-thyroid substances ; study of Addison's Disease ; investigation of active principles of Gorse (*Ulex Galii*) ; investigation of the effects of ionizing radiation on endocrine glands.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Physics	Professor W. SUCKSMITH, F.R.S.	Ferromagnetic properties of metals and alloys ; electrical conductivity problems ; infra-red investigations.
Physiology	Professor G. A. CLARK	Anaphylaxis ; investigations of gastric and pancreatic secretion ; the pulse wave in human subjects.
Zoology	Professor L. E. S. EASTHAM	Studies on the gill movements of ephemerial nymphs ; effects of temperature humidity on the life of the grain weevil ; conductory system of the human, porpoise and aligator hearts ; food associations and ecology of the seashore ; structure and physiology of the cuticle of myriapods.

XIV. UNIVERSITY OF ST ANDREWS

(*including* UNIVERSITY COLLEGE, DUNDEE)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	**Professor D. RUTHERFORD DOW**	Physico-chemical structure of neurofibrils in fixed tissues ; nature of neurofibrils or their precursors in living tissue ; anthropometric observations on female students ; enzyme preparation used in the treatment of chronic rheumatic disease.
Bacteriology	**Professor W. J. TULLOCH**	Investigation dealing with the epidemiology of diptheria ; elaboration of simple methods for determining the presence of phosphotase ; general work on virus infections, notably *Lymphogranuloma inguinale*.
Botany	**Professor R. J. D. GRAHAM**	Development studies of the bud and the stele in the Dicotyledon ; investigation into fruit growing in the Carse of Gowrie, including the anatomical changes induced by viruses in the raspberry ; studies in the maritime and fresh water flora of East Fife ; influence of short-wave radiation on plant growth particularly with regard to vegetative propagation and the lethal effects on wood destroying fungi ; investigation of the heather fungi.
Chemistry	**Professor J. READ, F.R.S.** **Professor W. F. K. WYNNE-JONES**	Stereochemistry ; chemistry of terpenes and camphors ; essential oils ; chemical and biochemical relationships in the genus Eucalyptus ; carbohydrates ; photochemistry ; alchemy and historical chemistry. Ionization of acids and bases in different solvents and the thermodynamics of the ionization process ; mechanism of chemical reactions and the use of isotopes in the study of such reactions ; electrodeposition of metals and the mechanism of over-voltage ; corrosion of metals in non-aqueous systems.
Engineering	**Principal A. R. FULTON**	Continuation of investigation on the process of combustion in the compression-ignition engine.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Mathematics	Professor H. W. TURNBULL, F.R.S. Professor E. T. COPSON	Studies of higher algebra and algebraic geometry, including Invariant Theory, the Theory of Groups and geometrical interpretation. Electrical methods of computing and solving differential equations ; wave propagation, refraction and diffraction of acoustic and electro-magnetic waves.
Natural History	Professor A. D. PEACOCK	Studies in biology and control of Pharoah's Ant ; studies in biology and control of Scottish midges ; studies in insect chitin.
Physics	Professor J. T. RANDALL, F.R.S. Professor G. D. PRESTON	Biophysical problems, including the effect of supersonic vibrations on living cells, and the study of gels. X-ray diffraction ; lead oxides ; Bragg X-ray microscope and experimental X-ray tube in early stages of development.
Physiology	Professor R. C. GARRY	Relation between stimulus and nature of nervous response ; ascorbic acid and pantothenic acid and epithelail repair ; mechanism of penicillin production ; chemical constituents of vegetable extracts in relation to the penicillin production.
Physiology and Biochemistry	Professor P. T. HERRING	Constitution of chitin and chitose.

UNIVERSITY COLLEGES

XV. UNIVERSITY COLLEGE, HULL

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botany Department* R. D'O. GOOD Dr B. T. CROMWELL	Geographical distribution of angiosperms. Nitrogen metabolism in plants.
Marine Biology	*Oceanography Department* Dr C. E. LUCAS	Ecology of marine plankton in relation to fisheries—Continuous Plankton Recorder.
Zoology	*Zoology Department* Miss M. J. DURHAM P. G. 'ESPINASSE	Anatomy and metamorphosis of *Dermestes vulpinus* F.; morphology of *Sphyrion lumpi* (Kröyer) parasitic on *Reinhardtius hippoglossoides* (Walbaun 1792). Effect of hyaluronidase on localization of the effect of oestrone on vagina of mouse and breast-feather of Brown Leghorn capon.

XVI. UNIVERSITY COLLEGE, LEICESTER

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botany Department* T. G. TUTIN	Investigation of periodicity of plankton diatoms ; pollen analysis of lake sediments.
Chemistry	*Chemistry Department* Professor L. HUNTER	The hydrogen bond in organic chemistry ; meso-hydric tautomerism.
Physics	*Physics Department* Dr E. A. STEWARDSON	Electron scattering by thin films ; magnetic susceptibilities of solutions ; attenuation of supersonic waves.

XVII. UNIVERSITY COLLEGE OF NORTH WALES (BANGOR)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Agriculture	*Agricultural Department* J. B. CRAGG Professor R. ALUN ROBERTS	Sheep blow-fly. Plant ecology with special reference to economic history.
Agricultural Chemistry	Professor G. W. ROBINSON	Soil chemistry.
Botany	*Botany Department* Professor D. THODAY, F.R.S.	Developmental anatomy, taxonomy and ecology of fresh water and marine algae ; respiratory metabolism.
Chemistry	*Chemistry Department* Professor E. D. HUGHES	Kinetics and mechanism of reactions and their dependence on atomic and molecular structure.
Physics	*Physics Department* Professor E. OWEN	X-ray crystallography.
Zoology	*Zoology Department* Professor F. W. ROGERS BRAMBELL	Reproduction in wild rabbits in relation to problems of sterility and prenatal mortality in mammals.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botany Department* Professor C. G. C. CHESTERS	Mould growth with particular reference to soils.
Chemistry : **(i) Organic** **(ii) Physical**	*Chemistry Department* Professor J. M. GULLAND, F.R.S.	Chemotherapy ; polynucleotides and nucleoproteins. Macromolecular and surface chemistry ; colloids and electrochemistry generally.
Engineering	*Electrical Engineering Department* Professor H. COTTON	General problems of electromagnetic machinery ; characteristics and applications of electric discharge lamps ; radio engineering.
Physics	*Physics Department* Professor L. F. BATES	Magnetic properties of matter.
Physiology	*Physiology Department* H. H. BARBER	Metabolism of amino-acids.
Textiles	*Textiles Department* Professor W. DAVIES	Applications of nylon yarns.
Zoology	*Zoology Department* E. J. W. BARRINGTON	Parasitology of fish ; ecology of fresh waters.

XIX. UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE (CARDIFF)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Anatomy	*Anatomy Department* Professor C. M. WEST	Early stages in the development of the human embryo ; development of the conducting system in the human heart.
Botany	*Botany Department* Professor R. C. MCLEAN	Angiosperms ; bacteria of rain ; microcinematography ; ecology of pond algae.
Engineering	*Engineering Department* J. C. BANNISTER	Minor researches on reinforced concrete.
Geology	*Geology Department* Dr L. R. MOORE Professor A. H. COX Dr W. D. EVANS	Palaeontological zoning of the Coal Measures. Stratigraphy of older rocks of Wales. Mineralogy of mine dusts in relation to lung diseases.
Histology	*Anatomy Department* T. H. BURLEND	Microscopic study of the effects of anoxia on the mammalian brain.
Metallurgy	*Metallurgy and Fuel Technology Department* Professor W. R. D. JONES R. C. HOWIE A. L. CARR	Alloys of magnesium. Isothermal transformation of steel ; constitution of metallic arc weld metal. Effect of magnesium on steel ; the ageing of low carbon steel.
Mining	*Mining Department* Professor T. DAVID JONES	Coal dust research ; lighting problems in mines.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Physics	*Physics Department* Dr A. J. C. WILSON	X-ray crystal analysis.
Physiology	*Physiology Institute* Professor T. GRAHAM BROWN, F.R.S.	Effect of anoxia on the central nervous system ; effects of antiseptics on bacterial population.
Zoology	*Zoology and Comparative Anatomy Department* Professor JAMES BROUGH Dr M. C. BROUGH Dr E. M. SHEPPARD G. E. H. FOXON Dr R. D. PURCHON	Vertebrate palaeontology (Fishes and Amphibians) ; systematics of Crustacea (Isopods) ; the Vertebrate heart ; physiology and anatomy of Lamellibranchs.

XX. UNIVERSITY COLLEGE OF THE SOUTH-WEST OF ENGLAND (EXETER)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Botany Department* Dr CALDWELL Dr A. S. BOUGHEY Dr M. M. RICHARDSON	Virus investigations : mosaic disease of Narcissus ; a new virus disease of Tomato ; movement of the virus agent in plants. Mycology : mildews and pathogenic fungi. Cytology.
Chemistry	*Chemistry Department* *Washington Singer Laboratories* Professor H. T. S. BRITTON Professor H. T. S. BRITTON H. G. BRITTON Professor H. T. S. BRITTON J. STONE Professor H. T. S. BRITTON B. HARRIS Dr S. J. GREGG K. S. W. SING Dr S. J. GREGG Dr K. SCHOFIELD	Complex formation in solution between inorganic compounds and organic acids, including hydroxy acids ; chemistry of the reactions and compounds of the rarer metals. Potentiometric titrations of hydrazine, semicarbazide, phenylhydrazine, reducing sugars and uric acid, with various oxidizing agents. Physico-chemical study of phosphomolybdic and phosphotungstic acids in solution. A physicochemical study of the reactivity of beryllium hydroxide with acids of various strengths. The adsorptive properties of alumina. The properties of adsorbed films on solids. The chemistry of cinnoline and related heterocyclic systems of potential chemotherapeutic interest.
Physics	*Physics Department* *Washington Singer Laboratories* Professor F. H. NEWMAN	Cold arcs ; refractive indices of gases ; magnetic properties of powders.
Zoology	*Zoology Department* L. A. HARVEY Dr R. S. HAWES E. BROADHEAD	Field studies of populations of Orthoptera ; analyses of faunas of garden soils. Protozoan parasitology — in particular Gregarine parasites of marine polychaetes and *Trichomonas vaginalis*. Studies on laboratory and field populations of closely related species of Psocidae.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Biology Department* Professor F. A. MOCKERIDGE Dr J. WILKINSON Dr M. J. REESE	Water-relations of the Bryophyta ; non-symbiotic nitrogen-fixation. Cytology of Ascomycetes, especially Rhytisma ; cytology of *Libaceae*, especially *Anthericum*, *Asphodelus* and *Asphodeline*. Microflora of streams in Gower ; physiological anatomy of prop roots.
Chemistry	*Chemistry Department* Professor J. E. COATES Dr L. E. HINKEL	Electrochemistry and general physical chemistry of solutions in anhydrous hydrogen cyanide. Organic and physico-chemical studies on the compounds of hydrogen cyanide with the halogen hydrides.
Engineering	*Engineering Department* Professor R. N. ARNOLD	Phenomena in the cutting of metals with special reference to vibration.
Geology	*Geology Department* Professor T. N. GEORGE	Upper palaeozoic Brachiopods ; carboniferous stratigraphy of South Wales ; applied crystallography ; geomorphology.
Mathematics	*Mathematics Department* Professor R. WILSON	Theoretical work dealing with problems in algebra and analysis.
Physics **(i) Experimental** **(ii) Theoretical**	*Physics Department* Professor F. LLEWELLYN Dr P. M. DAVIDSON	Ionization physics ; collision processes involving atoms, ions, electrons and photons ; the electric spark. Wave mechanics of optical spectra.

XXII. UNIVERSITY COLLEGE OF WALES (ABERYSTWYTH)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Agricultural Chemistry	*Agricultural Chemistry Department* R. O. DAVIES	The measurement of productivity on permanent and reseeded grassland ; long term effect of different forms of lime and fertilizers on hill swards.
Animal Health	*Animal Health Department* Professor A. N. WORDEN	The relationship between the quality of pasture and milk production ; animal breeding and nutrition ; the prevention and control of disease.
Physics	*Physics Department* * Dr R. M. DAVIES	Cosmic rays.
Plant Breeding	*Welsh Plant Breeding Station* Dr T. J. JENKIN	Plant breeding, with particular reference to grass and clover ; long term animal production experiment.

* Department possesses one high pressure chamber working up to 100 atmospheres and one large chamber, 2 ft. diameter, working at atmospheric pressure.

XXIII. WELSH NATIONAL SCHOOL OF MEDICINE (CARDIFF)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Pathology	Professor J. B. DUGUID	Histology of atherosclerosis in the human aorta with special reference to mural thrombosis; pneumokoniosis in South Wales coalworkers; artificial bronchial occlusion in the treatment of tuberculous cavitation of the lung; mechanism of plasma clot contraction.
Pharmacology	Professor R. St. A. HEATHCOTE	Action of drugs on invertebrates *in vitro*.
Surgery	J. GUNN ROBERTS	Action of stilboestrol in carcinoma of prostate, bladder, breast and oesophagus.

SECTION B

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

I. LIST OF RESEARCH ESTABLISHMENTS

Name of Research Establishment	Address	Director of Research
1. Building Research Station	Bucknall's Lane, Garston, Nr. Watford, Herts	Dr F. M. LEA
2. Chemical Research Laboratory	Teddington, Middlesex	Dr R. P. LINSTEAD, F.R.S.
3. Food Investigation Organization		
(a) Low Temperature Research Station	Shaftesbury Road, Brooklands Avenue, Cambridge	Dr C. S. HANES, F.R.S.
(b) Torry Research Station	Downing Street, Cambridge	Dr F. KIDD, F.R.S. (*Superintendent*)
(c) Ditton Laboratory	Aberdeen East Malling, Maidstone, Kent	Dr G. A. REAY (*Officer-in-Charge*) Dr C. WEST (*Superintendent*)
4. Forest Products Research Laboratory	Princes Risborough, Aylesbury, Bucks	Dr F. Y. HENDERSON
5. Fuel Research Station	Blackwall Lane, East Greenwich, London, S.E.10 (*Also Laboratories for Survey of National Coal Resources at Birmingham, Cardiff, Chester, Glasgow, Leeds, Newcastle, Nottingham and Sheffield*)	Dr A. PARKER

I. LIST OF RESEARCH ESTABLISHMENTS (*continued*)

Name of Research Establishment	Address	Director of Research
6. Geological Survey of Great Britain (and Museum of Practical Geology)	Exhibition Road, South Kensington, London, S.W.7	Dr W. F. P. McLintock
7. National Physical Laboratory	Teddington, Middlesex	Sir Charles Darwin, F.R.S.
8. Pest Infestation Laboratory	Biological Field Station, Slough, Bucks	G. V. B. Herford (*Officer-in-Charge*)
9. Road Research Laboratory	Harmondsworth, West Drayton, Middx.	Dr W. H. Glanville
10. Water Pollution Research Laboratory	Langley Road, Watford, Herts, and Minworth, Birmingham	Dr B. A. Southgate

II. LIST OF RESEARCH ASSOCIATIONS

Name of Research Association	Address	Telephone No.	Director of Research and Secretary
1. *Institution of Automobile Engineers (Automobile Research Committee)	*Laboratories* Great West Road, Brentford, Middlesex	Ealing 4741–2	*Secretary* Dr E. GIFFEN
	Office 12 Hobart Place, London, S.W.1	Sloane 2191–2	
2. The British Boot, Shoe and Allied Trades Research Association	*Laboratories and Office* 30–36 Thorngate Street, Kettering	Kettering 3528	*Director and Secretary* H. BRADLEY
3. The British Cast Iron Research Association	*Laboratories and Office* Alvechurch, Birmingham	Redditch 716	*Director and Secretary* J. G. PEARCE
4. The British Coal Utilization Research Association	*Laboratories* Coombe Springs, Coombe Lane, Kingston, Surrey, *and* Experimental Station, Rickett Street, West Brompton, London, S.W.6	Kingston 7204 Fulham 7881–4	*Director* Dr D. T. A. TOWNEND *Secretary* H. T. HATHAWAY
	Office 13 Grosvenor Gardens, London, S.W.1	Victoria 1534	

* Industrial research is carried out on a co-operative basis by this organization, which, for the purposes of the Government Scheme of Industrial Research, is regarded as equivalent to a Research Association.

Name of Research Association	Address	Telephone No.	Director of Research and Secretary
5. British Colliery Owners' Research Association	*Laboratories* Royal School of Mines, S.W.7 *Office* 4 Albert Hall Mansions, S.W.7		*Director and Secretary* J. I. GRAHAM
6. *The British Association of Research for Cocoa, Chocolate, Sugar Confectionery and Jam Trades	*Laboratories* 2 and 4 Dalmeny Avenue, Holloway, London, N.7 *Office* 57 Catherine Place, S.W.1	North 1048	*Director* Dr L. E. CAMPBELL *Secretary* T. A. H. SYCAMORE
7. British Coke Research Association	*Laboratories and Office* 11–12 Pall Mall, London, S.W.1	Abbey 6772–4	*Technical Officer* G. W. LEE *Secretary* F. GREENWELL
8. The British Cotton Industry Research Association	*Laboratories and Office* Shirley Institute, Didsbury, Manchester	Didsbury 2401	*Director* Dr F. C. TOY *Secretary* C. PACKER
9. The British Electrical and Allied Industries Research Association	*Laboratories* Wadsworth Road, Perivale, Greenford, Middlesex *Office* 15 Savoy Street, London, W.C.2	Perivale 4401 Temple Bar 7907, 8, 9	*Director* Dr S. WHITEHEAD *Secretary* R. A. MCMAHON

* Included in the Department's Food Investigation Organization.

II. LIST OF RESEARCH ASSOCIATIONS (*continued*)

Name of Research Association	Address	Telephone No.	Director of Research and Secretary
10. ***Research Association of British Flour Millers**	*Laboratories* Old London Road, St Albans, Herts *Office* 17 and 19 St Matthew's Avenue, Surbiton, Surrey	St Albans 640 Elmbridge 3759	*Director* Dr T. MORAN *Secretary* H. G. HALL
11. **†British Food Manufacturers' Research Association**	*Laboratories* 2 and 4 Dalmeny Avenue, Holloway, London, N.7 *Office* 57 Catherine Place, S.W.1	North 1048	*Director* Dr L. E. CAMPBELL *Secretary* T. A. H. SYCAMORE
12. **Gas Research Board**	*Laboratories and Office* 1 Grosvenor Place, London, S.W.1	Sloane 8266	*Director* Dr J. G. KING *Secretary* Dr W. T. K. BRAUNHOLTZ
13. **British Internal Combustion Engine Research Association**	*Laboratories and Office* 111–112 Buckingham Avenue, Trading Estate, Slough, Bucks	Slough 20295–6	*Director* Eng. Rear-Adm. D. J. HOARE *Secretary* Miss W. M. HORSFIELD
14. **British Iron and Steel Research Association**	*Laboratories and Office* (*temporary*) 11 Park Lane, London, W.1	Grosvenor 3263 and 3277	*Director* Sir CHARLES GOODEVE, F.R.S. *Technical Secretary* E. C. EVANS *Secretary* H. A. BRIDGES

***Controlled by the Ministry of Food during the war.** **†Included in the Department's Food Investigation Organization.**

Name of Research Association	Address	Telephone No.	Director of Research and Secretary
15. The British Launderers' Research Association	*Laboratories and Office* The Laboratory, Hill View Gardens, Hendon, London, N.W.4	Hendon 6111–2	*Director* F. C. HARWOOD *Secretary* Miss E. H. R. CARR
16. The British Leather Manufacturers' Research Association	*Laboratories* 1–6 Nelson Square, London, S.E.1 *Office* 8 St Thomas' Street, London, S.E.1	Waterloo 4432 Hop 0175	*Director* Dr DOROTHY JORDAN LLOYD *Secretary (Acting)* A. M. SOUTHALL
17. The Linen Industry Research Association	*Laboratories and Office* The Research Institute, Lambeg, Lisburn, Co. Antrim, N. Ireland	Lisburn 2255	*Director* Dr A. J. TURNER *Secretary* H. S. EATON
18. The British Non-Ferrous Metals Research Association	*Laboratories and Office* Euston Street, London, N.W.1	Euston 3372–3	*Director* G. L. BAILEY *Secretary* O. I. THOMAS
19. Research Association of British Paint Colour and Varnish Manufacturers	*Laboratories and Office* The Paint Research Station, Waldegrave Road, Teddington, Middlesex	Molesey 1063 and 2202	*Director* Dr L. A. JORDAN *Secretary* Dr S. H. BELL

II. LIST OF RESEARCH ASSOCIATIONS (*continued*)

Name of Research Association	Address	Telephone No.	Director of Research and Secretary
20. British Paper and Board Industry Research Association	*Laboratories and Office* 1 Buckingham Palace Gardens, S.W.1	Sloane 2346	*Director* Dr N. R. Hood *Secretary* F. H. Llewellyn Thomas
21. British Pottery Research Association	*Laboratories* Beechfield, Queens Road, Penkhull, Stoke-on-Trent *Office* Federation House, Stoke-on-Trent	Stoke-on-Trent 48741 Stoke-on-Trent 48631	*Director* Dr Marcus Francis *Secretary* S. H. Dodd
22. Printing and Allied Trades Research Association	*Laboratories and Office* Charterhouse Chambers, Charterhouse Square, London, E.C.1	Clerkenwell 8115-6-7	*Director and Secretary* Dr G. L. Riddell
23. The British Refractories Research Association	*Laboratories* The Mellor Laboratories, Shelton, Stoke-on-Trent *Office* Drayton House, 30 Gordon Street, London, W.C.1	Stoke-on-Trent 29119 Euston 2568-9	*Director* A. T. Green *Secretary* H. Halliday
24. The Research Association of British Rubber Manufacturers	*Laboratories and Office* 105-7 Lansdowne Road, Croydon, Surrey	Croydon 6105-6	*Director* Dr J. R. Scott *Secretary* Lt.-Col. B. J. Eaton

II. LIST OF RESEARCH ASSOCIATIONS (*continued*)

Name of Research Association	Address	Telephone No.	Director of Research and Secretary
25. The British Scientific Instrument Research Association	*Laboratories and Office* 26 Russell Square, London, W.C.1	Museum 2656	*Director and Secretary* A. J. PHILPOT
26. *The Scottish Shale Oil Scientific and Industrial Research Association	*Laboratories and Office* 53 Bothwell Street, Glasgow		*Secretary* H. R. J. CONACHER
27. The British Shipbuilding Research Association	*Laboratories and Office* 5 Chesterfield Gardens, Curzon Street, London, W.1	Grosvenor 8891	*Director* Dr S. L. SMITH *Secretary* J. C. ASHER
28. The British Welding Research Association	*Laboratories and Office* 2 Buckingham Palace Gardens, London, S.W.1	Sloane 9851–2	*Director and Secretary* A. RAMSAY MOON
29. The Wool Industries Research Association	*Laboratories and Office* 'Torridon,' Headingley, Leeds 6	Leeds 51047–8	*Director* B. H. WILSDON *Secretary* A. FROBISHER

* Not in active existence.

SECTION C

MEDICAL RESEARCH COUNCIL RESEARCH UNITS

1. **National Institute for Medical Research** Hampstead, London, N.W.3, and Mill Hill, London, N.W.7	*Director* C. R. HARINGTON, Ph.D., F.R.S. (*Biochemistry*) *Staff* H. KING, D.Sc., F.R.S. (*Chemotherapy*) C. H. ANDREWES, M.D., F.R.S. (*Virus Diseases*) A. S. PARKES, Sc.D., F.R.S. (*Endocrinology*) Sir PERCIVAL HARTLEY, C.B.E., M.C., Sc.D., F.R.S., and A. A. MILES, F.R.C.P. (*Biological Standards*) C. DOBELL, Sc.D., F.R.S. (*Protistology*) G. L. BROWN, M.B., M.Sc. (*Physiology*) P. BRUCE WHITE, B.Sc., F.R.S. (*Bacteriology*) F. HAWKING, D.M. (*Chemotherapy*) A. S. MCFARLANE, M.B., B.Sc. (*Biophysics*) and others
2. **Department of Clinical Research** University College Hospital Medical School, London, W.C.1	*Director* E. E. POCHIN, M.B., M.R.C.P.
3. **Clinical Research Unit** Guy's Hospital, London, S.E.1	*Director* R. T. GRANT, M.D., M.R.C.P., F.R.S.
4. **Neurological Research Unit** National Hospital for Nervous Diseases, Queen Square, London, W.C.1	*Director* E. A. CARMICHAEL, C.B.E., M.B., F.R.C.P.
5. **Otological Research Unit** National Hospital for Nervous Diseases, Queen Square, London, W.C.1	*Director* C. S. HALLPIKE, M.B., F.R.C.S., F.R.C.P.

6. **Radiotherapeutic Research Unit** Hammersmith Hospital, London, W.12	*Director* Miss C. A. P. WOOD, M.R.C.P., D.M.R.E.
7. **Electro-Medical Research Unit** Stoke Mandeville Hospital, Aylesbury	*Director* R. B. BOURDILLON, M.C., A.F.C., D.M.
8. **Dental Research Unit** King's College Hospital, London, S.E.5	*Director* J. D. KING, Ph.D., L.D.S.
9. **Experimental Medicine Research Unit** University of Cambridge	*Director* Professor R. A. MCCANCE, M.D., Ph.D., F.R.C.P.
10. **Human Nutrition Research Unit** National Hospital for Nervous Diseases, Queen Square, London, W.C.1	*Director* B. S. PLATT, C.M.G., M.B., M.Sc., Ph.D.
11. **Dunn Nutritional Laboratory** University Field Laboratories, Cambridge	*Director* L. J. HARRIS, Sc.D., Ph.D.
12. **Group for Research on Nutrition** Lister Institute of Preventive Medicine, London, S.W.1	S. S. ZILVA, D.Sc.
13. **Bacterial Chemistry Research Unit** Lister Institute of Preventive Medicine, London, S.W.1	*Director* Sir PAUL G. FILDES, O.B.E., M.B., F.R.S.

MEDICAL RESEARCH COUNCIL RESEARCH UNITS (*continued*)

14. **Group for Research in Chemical Microbiology** University of Cambridge	Miss M. STEPHENSON, Sc.D., F.R.S.
15. **Cell Metabolism Research Unit** University of Sheffield	*Director* Professor H. A. KREBS, M.D.
16. **Burns Research Unit** Birmingham Accident Hospital, Birmingham	*Director* L. COLEBROOK, M.B., F.R.C.O.G., F.R.S.
17. **Industrial Injuries Research Unit** Birmingham Accident Hospital, Birmingham	*Director* J. R. SQUIRE, M.B., M.R.C.P.
18. **Department for Research in Industrial Medicine** London Hospital, E.1	*Director* D. HUNTER, M.D., F.R.C.P.
19. **Pneumokoniosis Research Unit** Cardiff	*Director* C. M. FLETCHER, M.B., M.R.C.P.
20. **Group for Research in Industrial Physiology** London School of Hygiene and Tropical Medicine, W.C.1	T. BEDFORD, D.Sc., Ph.D.
21. **Applied Psychology Research Unit** University of Cambridge	Professor F. C. BARTLETT, F.R.S.

22. **Group for Research in Industrial Psychology** University of Manchester	S. WYATT, D.Sc.
23. **Group for Statistical Research** London School of Hygiene and Tropical Medicine, W.C.1	PROFESSOR A. B. HILL, D.Sc., Ph.D.
24. **Blood Products Research Unit** Lister Institute of Preventive Medicine, London, S.W.1	
25. **Blood Grouping Research Unit** Lister Institute of Preventive Medicine, London, S.W.1	*Director* R. R. RACE, M.R.C.S.
26. **Central Public Health Laboratory** Colindale Avenue, The Hyde, London, N.W.9	*Director* R. CRUIKSHANK, M.D., M.R.C.P., D.P.H. *Staff* V. D. ALLISON, M.D., D.P.H. (*Streptococcus Reference Laboratory*) A. FELIX, D.Sc., F.R.S. (*Enteric Reference Laboratory*) H. J. BENSTED, O.B.E., M.D. (*Standards Serological Reagents Laboratory*) MRS JOAN TAYLOR, M.B., B.S. (*Salmonella Reference Laboratory*)

SECTION D

AGRICULTURAL RESEARCH ESTABLISHMENTS

I. RESEARCH ORGANIZATIONS UNDER THE DIRECT CONTROL OF THE MINISTRY OF AGRICULTURE AND FISHERIES

Name of Research Organization	Director of Research	Location	Remarks
1. The Veterinary Laboratory	*Director* T. DALLING	New Haw, Weybridge, Surrey *Tel. No.* Byfleet 129	
2. The Foot and Mouth Disease Research Station	*Director* Dr I. A. GALLOWAY	Pirbright, Surrey *Tel. No.* Warplesden 24	Approval of Ministry of Agriculture and Fisheries necessary for visits
3. The Plant Pathological Laboratory	*Director* C. T. GIMINGHAM	Harpenden, Herts. *Tel. No.* Harpenden 199	
4. The Grassland Improvement Station	*Director* W. DAVIES	Dodwell-Drayton, Warwickshire *Tel. No.* Stratford-on-Avon 3057	
5. The National Institute of Agricultural Engineering	*Director* S. J. WRIGHT	Askham Bryan, Yorks. *Tel. No.* York 6421	

Name of Research Organization	Director of Research	Location	Remarks
6. The A.R.C. Field Station	*Director* Dr W. S. GORDON	Compton, Nr. Newbury, Berks *Tel. No.* Compton 57	
7. The Unit of Animal Physiology	*Director* Professor Sir JOSEPH BARCROFT, F.R.S.	Physiology Dept., Cambridge University *Tel. No.* Cambridge 3844	
8. The Unit of Soil Metabolism	*Director* Dr J. H. QUASTEL, F.R.S.	University of South Wales and Monmouthshire, Cathays Park, Cardiff *Tel. No.* Cardiff 340	Temporary location
9. The Unit of Insect Physiology	*Director* Dr V. B. WIGGLESWORTH, F.R.S.	Dept. of Zoology, Downing Street, Cambridge *Tel. No.* Cambridge 2708	See Sec. A IV
10. The Animal Breeding Research Organization	*Director* Professor R. G. WHITE *Chief Geneticist* Dr C. H. WADDINGTON	c/o National Provincial Bank Chambers, High Street, Bangor, and Hendon *Tel. No.* Hendon 7833	Temporary location

III. AGRICULTURAL RESEARCH ORGANIZATIONS FINANCED WHOLLY OR IN PART BY MAINTENANCE GRANTS MADE BY THE MINISTRY OF AGRICULTURE AND FISHERIES OR BY THE DEPARTMENT OF AGRICULTURE FOR SCOTLAND, AND UNDER THE GENERAL CO-ORDINATION OF THE AGRICULTURAL RESEARCH COUNCIL IN ASSOCIATION WITH THE MINISTRY

Name of Research Organization	Director of Research	Location	Remarks
11. Rothamsted Experimental Station	*Director* Dr W. G. Ogg	Harpenden, Herts *Tel. No.* Harpenden 3621	See Appendix IV
12. Long Ashton Research Station	*Director* Professor T. Wallace	Near Bristol *Tel. No.* Long Ashton 2181	Fruit and horticulture
13. East Malling Research Station	*Director* Dr R. G. Hatton, F.R.S.	East Malling, Kent *Tel. No.* Aylesford 7294	Fruit and horticulture See Appendix VIII
14. Horticultural Research Station	*Director* D. Boyes	Cambridge *Tel. No.* 76119	See Sec. A IV
15. Experimental and Research Station	*Director* Dr W. F. Bewley, C.B.E.	Cheshunt, Herts *Tel. No.* Waltham Cross 2150	Glasshouse crops
16. Plant Breeding Institute	*Acting Director* G. D. H. Bell	School of Agriculture, Downing Street, Cambridge *Tel. No.* Cambridge 2475	See Sec. A IV

Name of Research Organization	Director of Research	Location	Remarks
17. Welsh Plant Breeding Station	*Director* Professor T. J. JENKIN	Aberystwyth *Tel. No.* Aberystwyth 7145	See Sec. A XXII
18. Scottish Plant Breeding Station	*Director* W. ROBB	Corstorphine, Edinburgh *Tel. No.* Corstorphine 66081	
19. John Innes Horticultural Institution	*Director* Dr C. D. DARLINGTON, F.R.S.	Merton Park, Surrey *Tel. No.* Liberty 3645	See Appendix VI
20. Plant Virus Research Station	*Director* Dr K. M. SMITH, F.R.S.	Cambridge *Tel. No.* 2485	See Sec. A IV
21. Research Institute in Plant Physiology	*Director* Professor F. G. GREGORY, F.R.S.	Imperial College of Science, London *Tel. No.* Kensington 4861	See Sec. A X 2
22. Institute of Animal Pathology	*Acting Director* C. A. MCGAUGHEY	Cambridge *Tel. No.* Cambridge 5067	See Sec. A. IV

III. AGRICULTURAL RESEARCH ORGANIZATIONS FINANCED WHOLLY OR IN PART BY MAINTENANCE GRANTS MADE BY THE MINISTRY OF AGRICULTURE AND FISHERIES OR BY THE DEPARTMENT OF AGRICULTURE FOR SCOTLAND, AND UNDER THE GENERAL CO-ORDINATION OF THE AGRICULTURAL RESEARCH COUNCIL IN ASSOCIATION WITH THE MINISTRY (*continued*)

Name of Research Organization	Director of Research	Location	Remarks
23. Research Institute in Animal Pathology	*Director* Professor T. J. BOSWORTH	Royal Veterinary College, The Beeches, Streatley, Berks *Tel. No.* Goring 296	
24. Animal Nutrition Institute	*In charge* Dr J. HAMMOND, F.R.S.	Cambridge *Tel. No.* Cambridge 2485	See Sec. A IV
25. Rowett Research Institute	*Director* Dr D. P. CUTHBERTSON	Bucksburn, Aberdeen *Tel. No.* Bucksburn 8	Animal nutrition
26. National Institute for Research in Dairying	*Director* Professor H. D. KAY, F.R.S.	Shinfield, near Reading *Tel. No.* Spencers Wood 83103	
27. Hannah Dairy Research Institute	*Director* NORMAN C. WRIGHT	Kirkhill, Ayr *Tel. No.* Prestwick 7292–7293	

Name of Research Organization	Director of Research	Location	Remarks
28. Institute of Agricultural Parasitology	*Director* Professor R. T. LEIPER, F.R.S.	Winches Farm, St Albans, Herts *Tel. No.* St Albans 858 (*Dir.* St Albans 1968)	London School of Hygiene and Trop. Medicine See Sec. X 4 (*g*)
29. Animal Diseases Research Association	*Director* Dr J. RUSSELL GREIG	Moredun Institute, Gilmerton, Midlothian *Tel. No.* Edinburgh 79262	
30. Institute of Animal Genetics	*Director* Dr A. W. GREENWOOD	West Mains Road, Edinburgh, 9 *Tel. No.* Edinburgh 42567	See Sec. VI
31. Macaulay Institute for Soil Research	*Director* Dr D. N. MCARTHUR	Craigiebuckler, Aberdeen *Tel. No.* Aberdeen 7391	
32. Agricultural Economics Research Institute	*Director* Dr C. S. ORWIN	Parks Road, Oxford *Tel. No.* Oxford 2775	See Sec. A XII

IV. PROVINCIAL ADVISORY CENTRES OF THE MINISTRY OF AGRICULTURE AND FISHERIES

Name of Research Organization	Director of Research	Location	Remarks
1. Department of Agriculture, The University of Durham (King's College)	*Head of Department* Professor R. W. WHELDON	Newcastle-on-Tyne *Tel. No.* Newcastle 25998 and 23563	
2. Agricultural Advisory Department, The University of Manchester	*Head of Department* ARTHUR JONES	Manchester *Tel. No.* Ardwick 2681	
3. School of Veterinary Science, The University of Liverpool	Professor J. G. WRIGHT	Liverpool *Tel. No.* Royal 5460	
4. Department of Agriculture, The University of Leeds	*Head of Department* Professor N. M. COMBER	Leeds *Tel. No.* Leeds 28367	
5. Midland Agricultural College	*Principal* Professor H. G. ROBINSON	Sutton Bonington, Loughborough *Tel. No.* Kegworth 86	
6. Harper Adams Agricultural College	*Director* A. MCVICAR	Newport, Salop *Tel. No.* Newport 30	See Appendix V
7. Agricultural Advisory Department, The University of Bristol	*Director* Professor T. WALLACE	Long Ashton, Bristol *Tel. No.* Long Ashton 2181	

Name of Research Organization	Director of Research	Location	Remarks
8. Seale Hayne Agricultural College	*Principal* A. W. LING	Newton Abbot, Devon *Tel. No.* Newton Abbot 637	
9. Department of Agriculture and Horticulture, The University of Reading	*Professor of Agriculture* Professor H .G. SANDERS	Reading *Tel. No.* Reading 4422	
10. South-Eastern Agricultural College	*Principal* D. SKILBECK	Wye, Ashford, Kent *Tel. No.* Wye 1	
11. School of Agriculture, Cambridge	*Secretary* R. EDE	Cambridge *Tel. No.* Cambridge 2485	
12. School of Agriculture, University College of North Wales, University of Wales	*Head of Department* Professor G. W. ROBINSON	Memorial Buildings, Bangor *Tel. No.* Bangor 99	
13. Agricultural Buildings, University College of Wales, University of Wales	*Principal* IFOR L. EVANS	Aberystwyth *Tel. No.* Aberystwyth 346	
14. Agricultural Advisory Department, University College of South Wales and Monmouthshire, University of Wales	*Head of Department* J. REES	Cathays Park, Cardiff *Tel. No.* Cardiff 7282	

IV. PROVINCIAL ADVISORY CENTRES OF THE MINISTRY OF AGRICULTURE AND FISHERIES (*continued*)

Name of Research Organization	Director of Research	Location	Remarks
15. The Edinburgh and East of Scotland College of Agriculture	*Principal* Dr S. J. WATSON	13 George Square, Edinburgh, 8 *Tel. No.* Edinburgh 42017	
16. The West of Scotland Agricultural College	*Acting Principal* JOHN KIRKWOOD	Blythswood Square, Glasgow, C.2 *Tel. No.* Douglas 2241–2	
17. The North of Scotland College of Agriculture	*Principal* Professor H. W. BYWATER	Marischal College, Aberdeen *Tel. No.* Aberdeen 8351–2	

V. SOME OTHER ESTABLISHMENTS AT WHICH AGRICULTURAL RESEARCH IS CARRIED OUT

Name of Research Organization	Director of Research	Location	Remarks
Royal (Dick) Veterinary College	*Acting Principal* Professor D. C. MATHESON	Summerhall, Edinburgh, 9 *Tel. No.* Edinburgh 41087	
Glasgow Veterinary College	*Principal* A. A. FORSYTH	83 Buccleuch Street, Glasgow *Tel. No.* Douglas 0419	

Name of Research Organization	Director of Research	Location	Remarks
National Institute of Agricultural Botany	*Director* *Vacant*	Cambridge *Tel. No.* Cambridge 76201	
National Institute of Poultry Husbandry	*Director* A. McVicar	Harper Adams Agricultural College, Newport, Salop	See Appendix V
Department of Zoology	*Director* Professor James Gray, F.R.S.	Downing Street, Cambridge	Work on wireworm control
Department of Biochemistry	*Director* Professor A. C. Chibnall, F.R.S.	Downing Street, Cambridge *Tel. No.* Cambridge 4361	Helminthiasis in lambs
Dunn Nutritional Laboratory (M.R.C.)	*Director* Dr L. J. Harris	Milton Road (Field Laboratory), Cambridge *Tel. No.* Cambridge 2539	Accessory food factors
Ditton Laboratory (D.S.I.R.)	*Officer in Charge* Dr C. West	East Malling, Kent *Tel. No.* Aylesford 7256	Cold storage of fruit, see Sec. B I

V. SOME OTHER ESTABLISHMENTS AT WHICH AGRICULTURAL RESEARCH IS CARRIED OUT (*continued*)

Name of Research Organization	Director of Research	Location	Remarks
Low Temperature Research Station (D.S.I.R.)	*Superintendent* Dr F. KIDD, F.R.S.	Downing Street, Cambridge *Tel. No.* Cambridge 4477	Cold storage of vegetables, meat and milk, see Sec. B I 3
Water Pollution Research Laboratory (D.S.I.R.)	*Director* Dr B. A. SOUTHGATE	Broadlands, Langley Road, Watford, Herts *Tel. No.* Watford 4477	See Sec. B I
Pest Infestation Laboratory (D.S.I.R.)	*Officer in Charge* G. V. B. HERFORD	Biological Field Station, Slough, Bucks *Tel. No.* 21295	See Sec. B I
The Forest Products Research Laboratory (D.S.I.R.)	*Director* Dr F. Y. HENDERSON	Princes Risborough, Bucks *Tel. No.* 101	See Sec. B I
Department of Chemical Pathology, University College Hospital	*Director* Dr C. RIMINGTON	Gower Street, London *Tel. No.* Euston 5050	Induction of lactation in barren cows
Department of Botany, Imperial College of Science	*Director* Professor W. BROWN, F.R.S.	London *Tel. No.* Kensington 4861	Cultivation of vegetable and oil seed crops, see Sec. A X 2
Bureau of Animal Population	*Director* C. S. ELTON	University Museum, Oxford *Tel. No.* Oxford 4261	See Sec. A XII

Name of Research Organization	Director of Research	Location	Remarks
Research Units of H.M. Forestry Commission	*Director* W. H. GUILLEBAUD	25 Saville Row, London, W.1 *Tel. No.* Regent 2688	See also Sec. A XII, Sec. A X (i), and Appendix IV, p. 121

SECTION E

FISHERIES RESEARCH ORGANIZATIONS

I. UNDER DIRECT CONTROL OF THE MINISTRY OF AGRICULTURE AND FISHERIES OR SCOTTISH HOME DEPARTMENT

Name of Research Organization	Director of Research	Location	Remarks
Fishery Research Laboratory	*Director* G. M. GRAHAM	The Esplanade, Lowestoft	
Fishery Research Experimental Station	*Director* R. E. SAVAGE	Castle Bank, Conway, Carnarvon	
Marine Laboratory (*Scottish Home Department*)	*Director* Dr R. S. CLARK	15 Dee Street, Aberdeen	

II. INDEPENDENT RESEARCH ESTABLISHMENTS (receiving government aid)

Plymouth Laboratory, Marine Biological Association	*Director* Dr F. S. RUSSELL, F.R.S.	Citadel Hill, Plymouth	
Dove Marine Laboratory (*King's College, Newcastle-on-Tyne*)	*Director* A. D. HOBSON	Cullercoats	See Sec. A V 1
Marine Biological Station (*University of Liverpool*)	*Director* Dr R. J. DANIEL	Port Erin, Isle of Man	See Sec. A IX
Wray Castle Laboratory, Fresh-water Biological Association	*Director* Dr E. B. WORTHINGTON	Wray Castle, Ambleside	
Millport Laboratory, Scottish Marine Biological Association	*Director* R. ELMHIRST	Marine Station, Keppel Pier, Millport, Isle of Cumbrae	See also Sec. B I 3, Torry Research Station, and Sec. A XV, Marine Biology, University College, Hull*

* Work on fertilization of Scottish lochs is also in progress in Edinburgh (Dr F. Gross).

SECTION F

VARIOUS RESEARCH ESTABLISHMENTS ATTACHED TO MINISTRIES AND OTHER GOVERNMENT ORGANIZATIONS

(excluding Service and Supply Departments and those included under Sections B, C, D and E)

Name of Research Establishment	Address	Director of Research
1. **British Museum (Natural History)***	Cromwell Road, South Kensington, London, S.W.7	Sir CLIVE FORSTER-COOPER, F.R.S.
2. **Royal Botanic Gardens)*** (*Ministry of Agriculture and Fisheries*)	Kew, Surrey	Sir EDWARD J. SALISBURY, F.R.S.
3. **National Gallery Laboratory** *	Trafalgar Square, London	F. I. G. RAWLINS
4. **Royal Observatories** (*a*) English (*b*) Scottish	Greenwich Blackford Hill, Edinburgh, 9	Sir H. SPENCER JONES, F.R.S. Professor W. M. H. GREAVES, F.R.S.
5. **Science Museum**	Exhibition Road, South Kensington, London, S.W.7	Colonel E. E. B. MACKINTOSH
6. **Government Chemist's Department** (*The Treasury*)	13 Clement's Inn Passage, Strand, London, W.C.2	Dr G. M. BENNETT

* See Appendices for detail.

VARIOUS RESEARCH ESTABLISHMENTS ATTACHED TO MINISTRIES AND OTHER GOVERNMENT ORGANIZATIONS (*continued*)

Name of Research Establishment	Address	Director of Research
7. **Imperial Institute** (*Department of Overseas Trade*)	Imperial Institute Road, South Kensington, London, S.W.7	Sir HARRY LINDSAY
8. **Cereals Research Station** (*Ministry of Food*)	Old London Road, St Albans, Herts	Dr T. MORAN
9. **Safety in Mines Research Station** (*Ministry of Fuel and Power*)	Sheffield and London (Imperial College of Science, Royal School of Mines)	
10. **The General Post Office Research Laboratory**	Dollis Hill, London, N.W.2	Dr W. G. RADLEY

APPENDICES

I. BRITISH MUSEUM (NATURAL HISTORY)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Botany	*Department of Botany* *Keeper:* J. RAMSBOTTOM	Taxonomic work. (Phanerogram collections are still at Tring, but any specimens required can be made available in London at short notice.) Historical collections, drawings and manuscripts.
Entomology	*Department of Entomology* *Keeper:* E. B. BRITTON Dr H. E. HINTON Dr JOHN SMART A. W. MCKENNY HUGHES W. E. CHINA	Systematic entomology : Carabidae of New Zealand. Biology and systematics of stored product beetles. Distribution and systematics of insect vectors of disease. Economic entomology and insecticides. Trinidad soil fauna in connexion with diseases of Cacao.
Mineralogy and Petrology	*Department of Mineralogy* *Keeper:* Dr W. CAMPBELL SMITH	Systematic descriptive and determinative mineralogy ; X-ray methods of identification and study of crystal structure ; quantitative analysis and micro analysis ; meteorites.
Palaeontology	*Department of Geology* *Keeper:* W. N. EDWARDS	Eocene flora of Scotland ; evolution of Agnatha ; systematics of Jurassic Lamellibranchia ; morphology and systematics of Carnivora and Perissodactyla ; evolution and morphology of Plesiosauris and crocodiles ; distribution of fossil corals and mesozoic and tertiary Polyzoa ; palaeoecology of fossil Porifera and Bryozoa ; Jurassic and Recent Brachiopoda ; Cretaceous ammonites ; Pleistocene Mammalia of Mediterranean Islands and Palestine ; fossil insects ; time rate of evolution ; climate and chronology of Pleistocene.
Zoology	*Department of Zoology* *Keeper:* N. B. KINNEAR	No research. All available effort is being concentrated on getting the collections in order again.

Note : Many exhibition galleries are closed owing to war damage, but various collections can be seen, and the libraries are available for use.

II. ROYAL BOTANIC GARDENS

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
	Director Sir E. J. SALISBURY, F.R.S.	
	J. S. L. GILMOUR	Ecology and taxonomy of Philadelphus.
	The Herbarium	
	Dr W. B. TURRILL	Flora of Near East ; plant geography.
	Miss E. M. WAKEFIELD	Systematics of higher fungi.
	V. S. SUMMERHAYES	Tropical African orchids ; Australasian figs.
	F. BALLARD	African ferns.
	N. Y. SANDWITH	Flora of British Guiana.
	C. E. HUBBARD	Tropical African grasses.
	E. MILNE-REDHEAD	Flora of Rhodesia and East Africa.
	H. K. A. SHAW	Flora of British North Borneo.
	R. W. G. DENNIS	Systematics of higher fungi.
	P. H. B. TALBOT	Fungi of South Africa.
	Museums	
	Dr J. HUTCHINSON	Revision of Genera Plantarum.
	Dr F. N. HOWES	Vegetable gums and resins.
	Dr R. MELVILLE	Taxonomy of *Ulmus* ; pollen morphology and taxonomy.
	Jodrell Laboratory	
	Dr C. R. METCALFE	Taxonomic anatomy of Dicotyledons.
	Dr M. SKALINSKA	Cytology of *Valeriana dioica*.
	Dr C. L. HARE	Biology and morphology of *Eriocaulon septangulare*.
	Dr JANAKI AMMAL	Cytology of economic and ornamental plants.
	Dr PORTHEIM	Water culture of Cacti.

III. NATIONAL GALLERY RESEARCH LABORATORY

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
	Scientific Adviser F. I. G. RAWLINS	Investigations into the technique of the old Masters by means of X-ray ultra-violet and infra-red radiations ; colorimetry of pigments ; study of atmospheric pollution and its effects on paintings.

IV. ROTHAMSTED EXPERIMENTAL STATION

(*Director:* Dr W. G. Ogg)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Bees	*Bees Department* Dr C. G. Butler	Brood diseases and use of sulphonamides; pollination; effects of insecticides on bees; selective breeding; spring stimulation; feeding habits; biology of bumble bees.
Biochemistry	*Biochemistry Department*	Proteins in the normal and virus infected leaf, and the physical and phytopathological properties of leaf protein preparations with particular reference to pH.; preparation of antigen from *Brucella abortus* and the immunization of cattle against contagious abortion.
Botany	*Botany Department* Dr W. E. Brenchley	Effect of minor elements on growth, especially boron and molybdenum, and varying effects in different soils; effects of trace elements on the quality of flax fibre; changes in herbage produced by various manurial treatments; longevity of weed seeds; habits and morphology of wild oat; interaction of root temperature and light on the growth of plants; effects of long continued starvation on plant growth; effects of slag on botanical composition of pasture herbage; effects of seasonal rainfall and associated weather on first hay crop (in conjunction with Statistics Dept.)
Crop Physiology	*Crop Physiology Department* Dr D. J. Watson	Effects of agricultural treatments on yield in terms of the physiology of the crop; effects of plant diseases on yield; fertilizer requirements of specific crops, e.g. sugar beet, beans, flax; leaf growth and factors controlling cell division, expansion and differentiation; effect of soil conditions on distribution and activity of roots.

IV. ROTHAMSTED EXPERIMENTAL STATION (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Entomology	*Entomology Department* Dr C. B. WILLIAMS	Fluctuations due to climate in incidence of various pests, their parasites and enemies, including leather jackets, carrot fly, gall midges and slugs ; forecasts in changes of insect population ; statistical ecology of mixed animal and plant populations ; wireworms—individual growth and soil moisture effects ; biology of wireworm populations ; ecology of earthworms and their relation to soil fertility ; ecology of slugs ; methods of slug baiting ; gall midges of economic importance, including wheat-blossom midges and the accumulation of their larvae in the soil.
Field Experiments	*Rothamsted Experimental Farm* J. R. MOFFAT	Classical field experiments on wheat, barley, mangolds, hay and a Norfolk four-course rotation which have been in progress since 1843 ; long term rotation experiments to determine effects of fertilizers and cultivation treatments including leys ; evaluation of old pasture and leys ; manurial value of feeding stuffs fed to cattle ; bulky organic manures ; concentrated organic manures, e.g. processed casein ; fertilizer placement ; control of weeds by spraying.
	Woburn Experimental Station	The maintenance of fertility of light land ; effects of annual treatment with potash, phosphates and ammonium sulphate on a crop rotation of barley, clover, wheat, potatoes, rye and sugar beet ; effects of various green manures ; leys in the maintenance of fertility ; pot culture experiments on effects of manures on soil conditions and crops ; artificially fertilized market garden soil ; cultivation of soya bean and maize in England ; cause of infertility of acid soils ; swayback disease in sheep.

IV. ROTHAMSTED EXPERIMENTAL STATION (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Insecticides and Fungicides	*Insecticides and Fungicides Department* Dr F. TATTERSFIELD	Estimation of pyrethrin I by the Wilcoxen method ; synthesis of analogues of D.D.T. ; analogues of D.D.T., their differential toxic effects on various insect pests and their chemical constitution in relation to toxicity ; particle size of sprays and dusts in relation to toxicity ; test insects ; factors affecting resistance to insecticides in insects—species, strain, age, sex, food and environment ; survival of resistant variants ; effect of plant growth on protective action of D.D.T. ; laboratory techniques for assessment of toxicity of stomach poisons on insects ; effects of D.D.T. and persistent insecticides on beneficial insects and on the host-parasite relationship ; effect of persistent insecticides on plant insects, and of repellents and deterrents on plant infestation.
Pedology	*Pedology Department* Dr MUIR	Study of soil development and classification ; X-ray methods of identification of clays ; distribution of trace elements.
Plant Pathology	*Plant Pathology Department* F. C. BAWDEN	Viruses and virus diseases: the purification of viruses and study of their physical, chemical and serological properties ; cytology of virus infected plants by electron microscopy ; relationships between viruses and their insect vectors ; surveys of insects attacking potato and sugar-beet crops in relation to virus diseases ; manner of spread of Potato Virus X ; effects of nutrition of host plant on susceptibility to virus disease. Mycology: soilborne fungi and the environmental factors affecting their survival, especially *Helicobasidium purpureum* and *Plasmodiophora brassicae* ; saprophytic behaviour of *Rhizoctonia solani* ; nutrition and cultivation of wheat in relation to survival and rate of spread of *Cercosporella herpotrichoides* ; relation of lodging to eyespot and loss involved ; tuber rot in potato clamps.

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Soil Chemistry	*Chemistry Department* Dr E. M. CROWTHER	Chemical aspects of soil fertility ; availability of plant nutrients ; development of rapid analytical methods for advisory work ; fertilizer requirements of sugar beet, flax and peas ; bulky organic manures, their preparation, breakdown in the soil, seasonal and cumulative effects, with particular reference to the availability of phosphoric acid and any toxic ingredients ; soil phosphates and phosphatic fertilizers, their solubilities, rates of action and associated physicochemical equilibria ; defluorination of rock phosphate ; uptake of nutrients from soil under varying manurial conditions ; the effect on sugar beet of applications of sodium nitrate and ammonium sulphate with and without salt ; spectrographic methods for crop and soil analysis by Lundegardh and Arc methods ; zinc determination by polarograph ; mineral deficiencies in soil with particular reference to boron and manganese ; mineral deficiency in relation to virus disease ; attempt in conjunction with Statistics Dept. to ascertain how far sampling and analysing pasture yields by means of movable cages can estimate feeding value as shown by recorded live weight increases of cattle and sheep ; analysis of the effects of composts and fertilizers on the nutrition of tree seedlings in forest nursery soils (in conjunction with Forestry Commission) ; stability and composition of mica in various soils ; free alumina and its forms ; structure of complexes formed by high temperature phosphates ; climatic factors in the distribution of the major soil groups.
Soil Microbiology	*Soil Microbiology Department* Dr H. G. THORNTON, F.R.S.	Counting methods ; influence of artificial and organic manures, and the seasons on the micropopulation of soil ; food selectivity of soil protozoa (particularly giant rhizopods) and the Acrasiae group in relation to the bacterial population of the soil ; the role in the soil generally of soil protozoa, the Acrasiae and Myxobacteria ; soil Actinomycetes, and [*continued on next page*

IV. ROTHAMSTED EXPERIMENTAL STATION (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Soil Microbiology —*continued*	*Soil Microbiology Department* Dr H. G. THORNTON, F.R.S.	their action on soil bacteria ; functions and effects of mycorrhizal fungi ; quantitative estimation of fungal mycelium in soils ; relation of soil organisms in the rhyzosphere to the phosphorus cycle ; effective and ineffective strains and variants of nodule bacteria associated with leguminous plants (*Rhizobium*), and the action on them of bacterio-phages ; the relationship between the genetic structure of the host plant and its reaction to *Rhizobium* ; symbiosis and parasitism ; competition in the soil between strains of *Rhizobium* and its effects on inoculation technique ; action of soil micro-organisms on resins (in conjunction with the Road Research Board.
Soil Physics	*Soil Physics Department* Dr B. A. KEEN, F.R.S.	Physical characterization of soils including mechanical composition ; pore space ; water-holding capacity of soil ; absorption of gases and vapours by soils and clays ; retention of ions by clay and soil organic matter ; effect of meteorological conditions on transpiration from grass and evaporation from bare soil ; subsoiling ; deep and shallow ploughing ; rotary cultivation ; inter-row cultivation ; seed bed preparation ; vapour pressures of pure sugar solutions in relation to investigations on honey.
Statistics	*Statistical Department* Dr F. YATES	The statistical department co-operates with all other departments and undertakes researches with the following aims : To assist in the planning of field and laboratory experiments so that results may yield the maximum information after mathematical treatment ; to improve and develop methods for the analysis and summarizing of experimental data involving a large number of variables ; planning and execution of surveys and new techniques of sampling.

V. HARPER ADAMS AGRICULTURAL COLLEGE

(*Director:* A. McVicar)

Subject	Name of Laboratory or Department	Detail of Research
Chemistry	W. Morley Davies	Soil survey of the West Midlands ; field work on trace elements.
Dairy Bacteriology	Dr L. C. F. Clegg	The effect of different temperatures of storage on the keeping quality of milk ; various methods for assessing keeping quality of milk ; high temperature short-time pasteurization on a laboratory scale.
Entomology	H. C. Newton	Use of D.D.T. and Gammerane in the control of various pests, including carrot fly, the vegetable flies, and possibly wireworm.
Mycology	N. C. Preston	Club Root (*Plasmodiophora*) control.
Poultry	H. Temperton	Effects of thyroid-active supplements in diets for second year birds ; therapeutic agencies in the control of infectious entero-hepatitis in turkeys ; determination as to whether increased ovulation through artificial lighting is due to endocrine stimulation, or to increased food consumption.
Veterinary	D. W. P. Bythell	Penicillin therapy in bovine mastitis ; blackhead in turkeys ; manganese deficiency in dairy cattle associated with infertility ; Salmonella infections in cattle.

VI. JOHN INNES HORTICULTURAL INSTITUTION

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Cytology	*Director* Dr C. D. DARLINGTON, F.R.S.	Nucleic acids in relation to nuclear and cell behaviour.
Genetics	Dr K. MATHER	Inheritance of quantitative characters.
Horticulture	W. J. C. LAWRENCE	Treatment of crops ; soil sterilization ; composts.
Pomology	M. B. CRANE	Fertility ; induction of polyploids ; control of nuclear and cell division ; breeding of fruit trees.

VII. WELLCOME RESEARCH INSTITUTION

(*Director :* Dr C. H. KELLAWAY, F.R.S.)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Entomology	*Entomological Field Station*	Anatomy and histology of blood-sucking diptera.
Physiology	*Wellcome Physiological Research Laboratories, Beckenham*	Immunity ; diphtheria antitoxins and toxoids ; toxins of gas gangrene organisms ; pharmacological and chemotherapeutic researches.
Tropical Medicine	*Wellcome Laboratories,* 183 *Euston Road, London*	Morphological studies on protozoa ; helminth infection of small animals ; antigenic constitution of pathogenic leptospira ; experimental hepatitis ; production and stabilization of yellow fever vaccine ; micro-respiration studies ; synthesis of chemotherapeutic substances.
	Wellcome Chemical Research Laboratories, Beckenham	Synthetic chemotherapy.

VIII. EAST MALLING RESEARCH STATION

(*Director:* Dr R. G. Hatton, F.R.S.)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Biochemistry	*Director* Dr W. A. Roach	Methods of plant injection and of spectrographical and polarographic methods of analysis for diagnosis of mineral deficiency; curative methods
Entomology	Dr A. M. Massee	Life histories and control of insects and mites which attack fruit plants including fruit-tree red spider, apple blossom weevil, raspberry cane midge and strawberry insects.
Physiology	Dr M. C. Vyvyan	Vegetative propagation; plant hormones; the abscission process in relation to bud, leaf and fruit drop; control of preharvest fruit drop.
Plant Pathology	Dr R. V. Harris	The etiology and control of new or recently identified diseases of fruit plants; bacterial diseases of pome and stone fruits; Verticillium wilts; virus diseases, especially soft fruits and hops.
Plant Protective Chemistry	Dr H. Shaw	Insecticides, fungicides and bactericides; field trials; causes and amelioration of spray damage.
Pomology	Dr W. S. Rogers	Culture of hardy fruit trees; vegetative propagation; breeding; histological investigation of the relationship between anatomical structure and performance of rootstocks.
Statistics	T. N. Hoblyn	Design of experiments; variation studies; sampling methods.

IX. THE ROYAL TECHNICAL COLLEGE, GLASGOW

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry	*Chemistry Department* Professor W. M. CUMMING Professor F. S. SPRING	Chemotherapy of amidines, nitriles, and acridines; general study of Toxicology—reaction between nitrobodies and proteins; chemical engineering studies—heterogeneous catalysis, flotation, molecular distillation. Investigations of some antibiotics including aspergillic acid and patulin; a study of various aspects of the chemistry of the cardiac glycosides; synthesis of nucleosides of the xanthosine type by a novel reaction; investigations of the latex from various *Euphorbiaceae*.
Civil and Mechanical Engineering and Applied Mechanics	*Engineering Department* Professor W. KERR	Water tube boilers: contamination of feed water in closed-feed circuits and its prevention; investigation of heat transfer in tube banks and influence on natural circulation. Internal combustion engines: lubrication investigations on bearings and crossheads under fluctuating load conditions; rigidity of built-up crankshafts. Refrigeration: development of small refrigerating plants; thermodynamic and wear studies; hydrodynamic characteristics of valves. Civil engineering: investigations of scour and model experiments on scour control at River Clyde tidal weir; stability of saturated sands. Hydraulics: investigations of pressure distribution and velocities in centrifugal impellers and volutes. Structural engineering: behaviour of thin cold rolled sections; buckling of latticed columns by graded model tests; plastic flow conditions in structural elements; correlation of photo-elastic and fatigue investigations on models of ships' plating at hatch openings.
Mathematics	*Mathematics Department* Professor R. O. STREET	Configurations in Higher Space; high speed flow of a compressible fluid.

IX. THE ROYAL TECHNICAL COLLEGE, GLASGOW (*continued*)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Metallurgy	*Metallurgy Department* Professor R. HAY	The influence of chemical and physical properties of coke on blast furnace performance ; investigations of the constitution of slag-forming systems by thermal, microscopic and X-ray methods ; investigations of the viscosity, surface tension and specific heat of the systems pertaining to ferrous metallurgy ; determination of dissociation pressures of oxide systems and slag/metal relationships at high temperatures (circa 1,600° C.)
Pathology	*Department of Pathology* Professor D. F. CAPPELL Dr J. F. HEGGIE Dr J. S. F. NIVEN Dr A. C. LENDRUM	Researches on blood groups and iso-immunisation, with special reference to Rh antigens. Experimental nephritis. Serology of rikettsial diseases ; histology of the spontaneous mouse lung virus infections. Rheumatic diseases and hyperergic inflammations ; pathology of the heart in fatal diphtheria ; researches on histological technique.
Pharmacy	Professor J. P. TODD	The chemotherapy of wounds and the treatment of burns.
Physics	*Physics Department* Professor J. S. RANKIN	Experiments on the physical nature of cavitation ; physical changes under heating by high frequency currents.

X. COLLEGE OF TECHNOLOGY, MANCHESTER

(*Principal:* Dr J. E. MYERS)

Subject	Name of Laboratory or Department Director of Research or Research Worker	Detail of Research
Chemistry (i) Applied; ii) Textile	*Chemistry Department*	Various organic chemical investigations including kinetic studies, chlorination by tertiary butyl hypochlorite, and studies of alpha-oxidation; the time variation of surface and interfacial tensions; hop antiseptics and the microbiological oxidation of glucose; studies on the efficiency of fractional distillation of binary mixtures. Orientation and crystallization of viscose yarns; dye absorption; tensile strength etc.
Engineering (i) Mechanical; (ii) Electrical	*Engineering Department*	Powdered fuel; lubricating oil additives; stresses in flat plates; stresses in aero structures; problems in the discharge of certain types of weirs and Venturis; design and action of screw taps; cutting tool research; hydraulic torque converter. Transmission problems; electrical measurements.
Physics	*Physics Department*	X-ray diffraction of organic crystals.

MORNING SUBJECT (a)

A SURVEY OF SOME OUTSTANDING PROBLEMS IN AGRICULTURAL SCIENCE IN THE EMPIRE

Steering Group

Chairman—Sir Frank Engledow, F.R.S.

Recorder—Mr F. Hanley

Dr E. S. Archibald
Mr A. G. Beattie
Khan Bahadur Mian Mohammed Afzal Husain
Sir Theodore Rigg
Dr A. R. Saunders
Dr H. C. Trumble

Report

The steering group for this discussion took the view that agriculture, as an art, could draw upon the services of scientists in many fields, and that the object of the discussion should be that of bringing out certain important current scientific requirements of agriculture in the Commonwealth.

With the above object, the discussion was divided into three parts, namely: 1. Outstanding scientific needs connected with the soil. 2. Scientific needs concerned with the plant. 3. Scientific needs concerned with the farm animal.

The Soil

Special emphasis was laid on the importance of soil surveys to serve as a guide to the proper utilization and development of the land. Such surveys require a common system for the classification of soils, according to their pedological, chemical, mineralogical and other features. The soil surveyor should keep in closer touch than hitherto with the ecologist, recording the vegetable and animal life in the chosen territory. It was felt that further work was needed to discover basic facts concerning the supply of nutrients to crops, as well as the influence of organic matter on soil fertility and anti-erosive properties of the soil. Reference was made also to the increase in food production that is possible in some parts of the Commonwealth by increased knowledge of the water-holding and water-supplying capacity of soils. This would be particularly important in connexion with irrigation and land drainage.

The Plant

Crop pests and diseases and methods of their control were discussed. More fundamental knowledge is required about the factors of resistance of plants to various forms of parasitic attack, and increased research is needed into the possibility of breeding varieties resistant to disease. Plant breeding to improve crop production is in need of a greater variety of plant species on which to work, and for this purpose it was felt strongly that plant collecting expeditions should be organized. The plants so collected should be grown and studied at specially selected centres.

The Animal

Research in animal physiology is very much needed if animal breeding and veterinary practice are to make much further headway. Further study is especially needed of the possibilities of selection and breeding of local stock, in order to develop new strains capable of standing up not only to high temperatures and humidity, but to primitive methods of animal husbandry, particularly in East Africa and India.

General

Various chemical elements, such as iron and copper, are required by plants and animals in minute quantities. In many parts of the Empire both crops and animals suffer from a deficiency of one or the other of the trace-elements. Further research is required into the cause and treatment of such deficiencies, and into the functions of the diverse trace-elements in plant and animal life.

Note

Recommendations that soil and land-use surveys should be undertaken were made at discussion (j) on land utilization and soil conservation.

Recommendations

1. A conference of soil surveyors and pedologists should be set up to consider the development of soil surveys in general and to co-ordinate methods of soil classification.
2. Work is required on the structure of clays, of humus, and of the clay-humus complex, requiring advance of technique in studying finely divided material.
3. Work is required on the ion-water atmosphere surrounding colloidal bodies, including living organisms, root hair, and on the structure and binding force of the water. This should include a study of reaction in interpenetrating atmospheres.

   [2 and 3 together should throw much light on the agricultural problems of soil structures, aggregation and stability to alternations of wetting and drying, anti-erosion properties, availability and fixation of plant nutrients and inhibition of uptake of one plant nutrient in the presence of another (e.g. Ca:K balance).]
4. Further study is required in the subject of soil microbiology. This should include the relation of soil micro-organisms to soil organic matter, the availability of inorganic plant nutrients and plant pathology as well as such taxonomic work as may be necessary.
5. It is recommended that efforts should be made to evolve both methods and apparatus for studying the nature of the stress-strain relationships in soil in particular relation to cultivations.
6. Special study is required of the developmental and physiological action of the root in relation to its environment. This involves the study of
   (a) the water relations ;
   (b) the mineral relations of the root as well as root secretions and excretions.

7. Physiological development of plants in relation to environment, especially temperature and light (intensity, duration and quality and therefore artificial and natural ' shade ') should be studied.

8. Investigations are required on the following problems :

(a) quantitive inheritance ;

(b) incompatibility and sterility of wide crosses ;

(c) the induction of polyploids and the possibility of inducing desirable mutations ;

(d) breeding methods.

9. Investigations are needed on the epidemiology of fungal, insect and virus organisms and on pathogenic species in relation to strain specialization.

10. Further investigations should be made into methods of control of fungal, insect and virus attacks, especially the possibility of breeding for disease resistance and the nature of such resistance.

11. Climatic surveys, both regional and local, are accepted as a pre-requisite to the investigation of agricultural problems. There should be provided throughout the Commonwealth and Empire a series of meteorological stations measuring daily rainfall, free water surface evaporation, relative humidity, day and night temperature of the shaded and unshaded atmosphere and the quality and intensity of daylight.

12. Both reconnaissance and detailed soil surveys should be available as a basis for ecological and physiological investigations of the field problems and concerning agriculture.

13. Ecological studies of the natural vegetation should form part of regional surveys designed to afford an integrated pattern of climatic and soil relationships. For this reason, vegetational surveys need, whenever possible, to accompany soil surveys.

14. Animal physiology on a general basis and including all the chief domestic animals should be specifically studied. This is the need basic to research on nearly all kinds of practical livestock problems, including those of pathology. The study (biochemical and micro-biological) of ruminant digestion is a good example.

15. There is a dearth of men with ample knowledge of domestic animal physiology. Steps should be taken to encourage their training and their subsequent employment.

16. More knowledge is required of metabolism and enzyme systems of spermatozoa and of ova.

All through the session there was insistence on the manifest dependence of agricultural science on further developments in the basic sciences.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Mr Afzal Husain

It is evident that many problems of agriculture are common to many parts of the Commonwealth, but there are some which are peculiar to certain regions. The improvement of livestock in India is a problem which falls under the latter category. Although improvement of breeds is of significant importance, yet the fundamental problem in India is the provision of adequate and suitable food for the cattle. India's population of cattle is 200 millions, and there is a shortage of both roughages and concentrates. Ignoring the requirements of young stock, and only taking into consideration the requirements of 107 million bovine adults, the shortage of roughage is 50 million tons and of concentrates 9 million tons. It is evident that attempts to improve the breeds of milch-cattle and work-cattle must remain abortive until the food situation improves. I entirely agree with the view expressed by a previous speaker that of the livestock we should maintain the minimum number required for the needs of the human population. This is a very important consideration. Our need, in India, is a substantial reduction in the number of cattle, so that the remainder can be well fed. The pressure of human population on land is so great that not much land is available for growing fodder for cattle and they subsist mostly on stock and straw of grain crops. Reduction in the number of cattle is the only solution of the problem, and reduction can only be brought about by extensive mechanization of agriculture. This will be the first step towards the improvement of livestock. Mechanization will be successful only if the project extends over a large area and tractors and other farm machinery are designed for Indian conditions and, to be cheap, manufactured within the country. This may not be directly relevant to the discussion, but this is the first necessary step towards the solution of a fundamental problem.

There is need for a careful study of the fundamental problems of live-stock industry. We want all the knowledge that we can get, so that we can employ it progressively all over the country as conditions improve and in tracts more favourably situated regarding cattle food immediately.

Mr H. R. Marston

Factors which limit efficiency in agriculture are surely as evident as they appear to be, and so a great deal of effort is spent on investigations which become concerned with symptoms rather than with underlying causes.

It is thus gratifying to find such a general expression of agreement on the need for more extensive research in the basic sciences related to agriculture.

Professor J. N. MUKHERJEE

In the opening discussion on the subject of 'The Soil' Professor J. N. Mukherjee said :

As desired by the steering group I propose to deal with some fundamental scientific problems relating to the subject of 'The Soil' of interest to practical agriculture. Soils are hetrogeneous systems consisting of solid particles of different substances having different shapes and sizes and of a liquid and a gaseous phase. The nature of these substances and their arrangements which determine their structural set-up also determine their behaviour to tillage operations and to hydration and dehydration ; their moisture holding and moisture yielding capacities ; and several other properties of interest to practical agriculture. The colloid fraction which constitutes the clay determines to a large extent many aspects of soil behaviour. X-ray diffraction, thermal analysis and the electron microscope have established that the clay fractions of different soils consist of varying proportions of a number of clay minerals. These clay minerals, as also the other constituents of soil, are characterized by their polar character, and their behaviour is dominated by their electrochemical properties of which base exchange is one. These properties of the individual constituents, as also of the ensemble either in the form of the colloid fraction or of the soil material, deserve detailed examination. X-ray and the other methods do not directly deal with these electrochemical properties which determine soil behaviour. Electrochemical investigations have shown that of the possible constituents of the clay fraction in its acid form hydrogen kaolinite has a dibasic character whereas hydrogen montmorillonite, behaves as a monobasic acid. The consistency and related plastic properties of these clay minerals vary widely from one soil to the other and there exist interesting relationship between their electrochemical and plastic properties. Besides the clay fraction is not uniform in its composition over the whole range of sizes of its particles. It seems also from electrochemical studies that there are more clay minerals in soils than those brought to light so far by X-ray studies. One interesting aspect of the electrochemistry of clays is that there are several features which are not consistent with what one would expect from the concepts of classical electrochemistry even as modified by the theories of Debye and subsequent workers. The electrical double layer has a structure which is not adequately represented by its modern counterpart, the ion atmosphere. It seems that developments in related branches of fundamental science do not always keep pace with the needs of the agricultural sciences, and may at times have to wait indefinitely for such suitable developments for progress in agriculture. In order to avoid such time lag and arbitrary conditions of progress in the solution of problems of practical agriculture, workers in the agricultural sciences should obviously take upon themselves the solution of the problems of fundamental research confronting them. They would thus help themselves and may also help workers in other fields.

There is scope for more fundamental work of this sort with concentrated suspensions and pastes made up from the clay fraction or of its individual constituents. At higher concentrations the hydrogen ion activity of hydrogen clays changes in a manner which indicates an increase in the activity co-efficient. Two fundamental changes seem to be brought about at higher concentrations ; the formation of some sort of structure and an overlap of mobile sheets of the double layer. The individual clay minerals possibly differ in their behaviour in these respects. The overlap of the ion envelopes may cause interchange between two particles and such an interchange is considered by some to occur between the surfaces of root hairs and of soil particles.

At the end of the discussion on the subject ' The Soil,' Professor Mukherjee drew attention to the importance of combining studies of plant associations and ecology in soil surveys and integrating the results of such studies in soil classifications based on the soil profile.

Sir Theodore Rigg (*Summary of Verbal Communication*)

After referring to papers presented by New Zealand scientists, Sir Theodore Rigg stated the major soil problems of New Zealand were connected with striking deficiencies of phosphate, lime and minor elements. Very noticeable progress had been made during the last fifteen years in the identification of minor element deficiencies which had retarded the development of large areas of land otherwise suitable for both dairying and fat lamb production. The identification of ' bush-sickness ' as a cobalt deficiency ailment of stock, and the establishment of practical and inexpensive methods for control, had enabled several hundred thousands of acres to be intensively farmed with great success. The more recent discovery of copper deficiency by the Department of Agriculture on many peat soils, particularly on the Hauraki Plains, had solved the problem of ' peat scours ' and was already having a highly beneficial effect, both on dairying and sheep farming on these soils.

Similar work had been done by the Cawthron Institute and the Department of Scientific and Industrial Research in connexion with boron and magnesium deficiencies of fruit in Nelson and Central Otago.

Further study of trace element deficiencies in New Zealand soils was required, and in addition work was urgently needed on phosphate fixation, the use of different types of phosphatic and nitrogenous fertilizers for pasture land.

The great importance of soil surveys and study of the characteristic properties of the more important soil types was fully realized by New Zealand workers, and every effort was being made to extend both reconnaissance and detailed soil surveys throughout the country. Of equal importance in the sound development of New Zealand agriculture were pasture surveys, the improvement of grasses suitable for both high and low rainfall country and increased knowledge concerning the organic constituents of grasses.

Professor H. C. Trumble

Professor H. C. Trumble (Australia) emphasized the need for an Empire financial pool from which funds could be drawn on request for collaborative

work. It was stated that financial support of this type from the Empire Marketing Board in 1927 had laid the foundation for the extensive programme of grassland researches that had eventuated in Australia subsequently. Under the terms of the original agreement three relatively junior men were secured from Great Britain for work in Australia, while an Australian proceeded to the Home Country for a year's training and experience. Unfortunately, the Empire Marketing Board terminated six years later and since then a similar fund has not been available.

A SURVEY OF SOME OUTSTANDING PROBLEMS IN AGRICULTURAL SCIENCE IN THE EMPIRE

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1. INTRODUCTION

AGRICULTURE was the first settled occupation of mankind. Without it, industry, the arts, literature and science itself have neither meaning nor future. Agriculture means the successful management of the soil, the plant, the animal severally and conjointly. The problems which thereby arise involve every branch of the natural sciences.

Therefore, and as the purpose of this Conference is essentially to look forward and not backward on past achievement, Dr Ogg, and Professors Brooks and Dalling, following out a suggestion made by Sir Frank Engledow, have set out some fundamental scientific problems, knowledge of which, or better the solution of which, should, in their opinions, materially assist agriculture. This has been done in the hope that specialists in other branches of pure and applied science may recognize some similarity to some of their own problems and may proffer their suggestions.

2. THE SOIL

Soil studies may be considered conveniently in two main groups. The first is concerned with the scientific study of the soil as part of our environment and the term pedology ($\pi\epsilon\delta o\nu$, soil or earth) is often applied to this branch of science. The second group deals with the utilization of soils for the purposes of agriculture, horticulture and forestry and is, therefore, concerned with maintaining or increasing soil fertility. It is proposed to outline briefly a few of the main problems confronting soil investigators and to indicate some of the directions from which assistance from other branches of science may be expected in solving these problems.

Some problems in pedology

Soils consist of weathered rocks together with varying amounts of organic matter and living organisms. There are many different kinds of soils and it is obviously necessary, as in other branches of science, to have a system of classification and to know as much as possible about the distribution of the objects being studied.

The Russians were the first to evolve a genetic system of soil classification. They discovered the fundamental importance of climate in determining soil type and recognized the zonal distribution of the major world groups of soils. Soil and climate influence vegetation which, again, in turn, affects soil type.

In describing a soil, a vertical section from the parent material to the surface is studied and this section or profile exhibits various layers or horizons which reflect the influence of climate, vegetation and other living organisms on the parent material.

The various soil types have their characteristic profiles and the field descriptions of these are supplemented by laboratory data. A good deal is known about the soil types of temperate regions, but even there our knowledge of the distribution of the products of weathering in the soil profiles is very far from complete. Probably microbiological influences play a greater part than has been recognized in the past.

Our knowledge of sub-tropical and still more of tropical soils is even less satisfactory, partly because they have been less intensively studied, but also because generally less exact data are available regarding the geological parent material, the climate and the vegetation. It is highly important to make a fuller study of soil types and to evolve a much better system of classification than exists at present. It is equally important to know the distribution of the various soil types. The need for geological surveys is never questioned but there has been reluctance in some countries, including our own, to undertake a stock-taking of the most important of our natural resources, the soil. Soil surveys provide a necessary basis for research and it is impossible to make adequate use of the results of research without a knowledge of the distribution of the various soil types. In Russia, a great deal of soil survey work has been done, and in the United States a fairly detailed survey has been practically completed. Canada, Australia, New Zealand and South Africa have surveys in progress though they could scarcely be described as well-advanced, whilst in Britain the work is still in its infancy and in the Colonial Empire almost non-existent.

The soil surveyor requires more assistance from the geologist, especially

more detailed information on the mineralogy and distribution of the surface deposits, and the geomorphology of land surfaces. The parent materials of many important tropical soils are essentially fossil residues from earlier weathering cycles. In the Colonial Empire, in particular, the lack of geological data is a serious handicap and the need for geological surveys of food producing areas cannot be too strongly urged. Additional meteorological data and ecological surveys are also much to be desired for application both in practical agriculture and in the interpretation of soil forming processes, as an aid to better soil classification.

Problems in soil fertility

In studying the problems of soil fertility help has been obtained from the chemist, the biochemist, the plant physiologist, the physicist, the microbiologist, the statistician and the engineer. Considerable progress has been made but at every stage this progress has depended on advances in the knowledge of the above mentioned branches of science.

The practice of adding compost, farmyard manure and, where necessary, lime is extremely old and in the past century food production has been increased enormously through the addition of nitrogenous, potassic and phosphatic fertilizers to soils. During the last twenty-five years the need for adding traces of other elements such as boron, manganese, copper, zinc and cobalt to certain soils has been recognized. Most of these elements are toxic if more than a trace is present in a readily available form. Our knowledge of them is still extremely limited and it is not even known how they act, though it has been suggested that they are catalysts. Another problem common to the trace elements and major plant foods is that of availability. Attempts have been made to devise methods of estimating the amount of plant nutrients present in soils in an available form but these are still somewhat crude and unsatisfactory. Nutrients applied in an available form in some cases become less readily available in contact with the soil. In the case of potassic fertilizers the question of availability is related to the phenomena of base exchange ; in the case of phosphatic fertilizers, there is a tendency to ' fixation ' by sesquioxides in acid soils and by calcium in alkaline soils. We still know very little, however, about the mechanism of this ' fixation ' and how to prevent it. Even the structure of phosphoric acid itself is not yet known, nor has the part played by oxidation reduction processes in the fixation by hydrous iron oxides been fully explored. Before these problems of availability can be solved more fundamental research on plant physiology is required and probably more attention should be given to soil microbiological studies as these have already provided useful results, for instance in manganese problems.

Further investigations are also required on the formation, composition, properties and decomposition of soil organic matter and on the part it plays in soil fertility. The problem is of particular importance in tropical soils because of the rapidity with which organic matter in these soils can be destroyed. The work on this subject in the past has been largely chemical but in addition to chemical work, it seems likely that biochemical and microbiological investigations would yield useful results.

Soil moisture is still another problem. Over much of the earth's surface, agricultural production is limited through either an excess or a deficiency

of water in the soil. Removal of the excess through land drainage is still an art, rather than a science. Physics and engineering, however, should in the future have much to contribute to the solution of drainage problems. At present little help can be obtained in answering the very practical questions as to depth and distance apart at which drains should be constructed. Lack of water is an even greater difficulty and more attention should be given to the problems of dry farming. In recent years work on soil physics at Rothamsted has led to a much better understanding of soil moisture and of the effects of cultivation, but much more requires to be done. The provision of water by irrigation still presents many problems to the chemist, the physicist and the engineer, and on the solution of these will depend our ability to feed the vast and increasing populations of countries like India and China.

Erosion is undoubtedly one of the most urgent, if not the most urgent, soil problem facing us to-day. Although of little consequence in Britain, it is extremely important in the Dominions, India and the Colonial Empire. The subject has been studied very intensively in the United States, but considering its importance inadequate attention would appear to have been given to it in the British Commonwealth, particularly in India and certain parts of the Colonies.

Other problems could be mentioned such as the influence of soil fertility on the composition of agricultural produce and on human health, the study of auxins or plant growth promoting substances and many more. The list, however, is not intended to be comprehensive but merely to indicate typical problems for the solution of which assistance is required from various branches of science.

Some recent scientific approaches to soil problems

Modern geochemistry is proving of value to soil science in various directions, for instance in studying the distribution of the products of weathering in the soil profile and thereby providing a sounder basis for soil classification, and also in studying the availability and regional distribution of plant nutrients including the trace elements. Developments in methods of quantitative spectrography both X-ray and optical in Goldschmidt's and other laboratories have been of great value in obtaining the necessary analytical data, particularly where only traces of the elements are present. Advances in the knowledge of crystal structures have permitted the determination of the atomic and ionic radii of a large number of elements and so enabled the prediction of their occurrence to be made. From thermochemical considerations a more fundamental explanation of the well known order of segregation of the elements in the earth has been provided, whilst consideration of ionic and atomic radii has shown in which minerals any given element might be found. The entry of ions or atoms into the three-dimensional network of crystals is determined by their relative sizes and the order of their entry by interatomic bonding forces. Thus iron and magnesium freely replace each other in olivine, but magnesium being slightly smaller enters the crystal first. In micas, lithium can replace magnesium only after most of the latter has entered the crystallizing mineral because lithium, although of the same size as magnesium, has the smaller charge. It is now possible to classify the elements on the basis of their ionic and

atomic radii into a number of groups within which isomorphous replacement is possible and so obtain a series of host minerals in which certain elements are likely to occur.

In the study of clay minerals, the ideas of isomorphous replacement have contributed largely to our present conceptions of their composition, particularly in the montmorillonite group, and also to the explanation of the presence or absence of base exchange. We are still far from a proper understanding of the real structure of many of the clay minerals and much more fundamental work on them is required as identification is not yet an easy matter.

As the minerals of igneous rocks become weathered in the course of soil and sediment formation, other principles may be expected to govern the distribution of the elements in sedimentary rocks and soils. It has been shown that the ionic potential (ionic charge/ionic radius) provides a clue to the problem. Thus elements of low ionic potential tend to form cations in solution (e.g. sodium, potassium, etc.), those of very high ionic potential form the central element of oxyacid anions, whilst those of intermediate ionic potential tend to remain as oxides or hydroxides (e.g. iron, titanium, aluminium, etc.). In soils, the hydrous oxides of certain metals are of considerable importance. Some specific forms of these oxides can be identified but the actual manner in which they are linked to organic matter and the clay minerals is unknown.

It is also of interest to note that the ionic potential has a bearing on the biological distribution of the elements. Considering only elements of essentially invariant valency in the oxidized part of the biosphere, it is found that below an ionic potential of 4 occur the normal biological cations, whilst above an ionic potential of 12 occur the major non-metallic elements (other than oxygen and hydrogen) which form the organic compounds of living matter.

The importance of water as a soil constituent and a factor in plant growth can scarcely be over-estimated and it is felt that further fundamental work on water along modern lines is urgently required. Our present knowledge of the molecular physics of water is very incomplete even compared with that of many other substances of much less importance. The bound water in soils seems to derive many of its essential properties from its association with the layer-lattice minerals either entering into their structures or being oriented at their surfaces or co-ordinated to the adsorbed bases. Recent progress in physical and physico-chemical methods with regard to bonding forces in crystals and in liquids and work (Mrs K. Lonsdale) on the thermal vibrations and absorption spectra of bonded atoms and molecules have opened up important possibilities of acquiring more knowledge of the fundamental properties of water. At the instigation of V. M. Goldschmidt the matter has been discussed recently at two meetings held at the Royal Institution and a group of workers has taken up various aspects of the problem.

Recent Rothamsted work has provided an analytical link between natural evaporation (from open water, bare soil and cropped surfaces) and weather elements, based on certain assumptions about wind structure and atmospheric turbulence and on the nature of the radiation exchanges between the sun and the soil, and between the soil and the atmosphere.

This work is directly applicable to the estimation of water loss from catchment areas, to the specification of the frequency and intensity of irrigation of farm and market garden crops, and, on a broader plane, to the classification of soil types and their evolution by providing a precise guide to the magnitude of an extremely important formative factor.

Further progress is largely dependent upon confirmation of the assumptions. This will involve more detailed study of the turbulent transfer of water vapour and heat in the atmosphere, a study that has wider agricultural implications than the solution of evaporation problems because it bears directly on the transport of dust, spores, pollen, insects, etc. On the radiation side, it will involve study of the reflection coefficients of various surface types, the nature of the long-wave radiation from the atmosphere and its dependence on water vapour content, and the way in which cloud amount and type controls the outward radiation from the earth.

(W. G. O.)

3. PLANTS

In the following remarks an attempt is made to indicate directions in which advances in our knowledge of plant life may assist the general application of science to agriculture. Botany is one of its basic sciences, and the chief branches of the study of plants which have bearings on the practice of agriculture are considered from the above standpoint.

Physiology

Much more information is required about the physiology of crop plants. Unfortunately there is a dearth of plant physiologists at present, and one of the most urgent needs of the future is increased emphasis on fundamental studies in plant physiology. The problems of the development of crop plants are extremely complex, and it is only by the integration of the work of teams of investigators that many of these problems can be solved. The attachment of a single physiologist to an agricultural research station will achieve little unless the man is of outstanding calibre, and even then progress will be very slow. What is wanted for the solution of the complex problems of crop growth is the establishment of teams of investigators, each team being led by a man of experience, great ability and broadness of outlook. The producer of crops is concerned with the integration of all the factors which determine plant growth and development, and it is basic knowledge of this integration which is at present deficient.

It is to advances in fundamental knowledge that we can look most hopefully for improvements in practice. One can never prophesy as to what particular accretion to knowledge will sooner or later have a practical bearing. An illustration will support the truth of this statement. For instance, who would have thought when work was commenced on the growth hormones (auxins) of seedling oats and other plants that allied substances would be found which are now used in practice as weedicides, for the prevention of fruit-drop, and for the parthenocarpic development of tomatoes and perhaps also of apples damaged by frost at flowering time ?

Some years ago the notable discovery was made that in certain plants

the time of flowering may be determined by the length of daylight to which the plants are exposed, some plants flowering only when subjected to short days and others flowering only after exposure to long days, although other factors may also be involved. Discovery of this kind of phasic development has been turned to account in practice although the physiological interpretation of this behaviour is still obscure. If a full explanation of these phenomena could be given further applications might well be achieved in practice.

Many crop failures are due either to deficient drainage or to lack of water at critical times. Far more attention should be paid to the water-relations of tissues, especially as regards the roots. A more adequate knowledge of this matter might lead to measures to tide over critical periods or might show where certain crops are bound to fail under specified environmental conditions. The substances secreted by roots are a fruitful subject of investigation for the future, and precise knowledge of these substances might have important practical bearings. It has been claimed that substances secreted by the roots of leguminous plants have an effect on other plants in the immediate vicinity. Again, it is known that a secretion from the roots of potatoes greatly stimulates the cysts of the potato eel-worm to germinate. Chemists are trying to determine the composition of this substance. If they succeed the way may be open to prepare the substance synthetically, and if it could be manufactured cheaply, the prospect of protecting this crop from one of its most menacing plagues is evident. But it is not only the roots which should be studied from this standpoint. The exhalations from leaves and fruits should also be investigated, as is clear from the discovery during a purely academic study of the respiration of leaves in the laboratory that the formation of small amounts of ethylene hasten the onset of senescence, a discovery which has led to the utilization of this gas for ripening certain kinds of fruits.

The detailed physiological study of particular crop plants, especially those in the tropics such as coffee, tea, cocoa, cotton and rubber, is certain to lead to fruitful results. A beginning has been made on a small scale, but much more comprehensive investigations are required. At present little is known about the physiology of latex production in the rubber tree, a surprising fact in view of the enormous economic interests at stake. Even with temperate crops intensive physiological investigations are most desirable. A complete physiological study of the potato plant, for instance, and of the many problems associated with storage of the tubers is certainly required. Our present knowledge of the potato plant is largely an aggregation of unrelated facts.

Brief mention only can be made of other branches of plant physiology the study of which is likely to have an influence on crop production. Much attention has been paid in recent years to crop failures caused by deficiencies of mineral substances, especially trace elements, and to the serious diseases of animals caused by grazing on herbage deficient in certain of these elements. Such advances in knowledge have increased production both in plants and animals. But the function of these trace elements in the physiology of the plant is still largely unknown. Again, further investigation is badly needed of frost injury to crop plants and as to what constitutes resistance to frost damage possessed by certain varieties. Lastly, the

physiological interpretation of genetic characters is a field still largely unexplored.

PATHOLOGY

There are many methods of approach to the control of the diseases and pests of crop plants, and here also it must be realized that even the most academic studies of plant parasites and insect foes may lead eventually to new viewpoints on the best ways of avoiding or ameliorating attack. There are still several important diseases and pests which are practically uncontrollable by present methods, and no effort should be spared in trying to devise novel measures for dealing with them.

Much is known about the detailed life histories of parasitic fungi and insect pests but we are often ignorant of their epidemiology and the precise amount of damage they cause. The first consideration also applies to the spread of virus diseases in the field.

Much success has been achieved in breeding varieties of crop plants resistant to certain kinds of parasitic fungi and resistant or tolerant to viruses ; further advances can be looked for in this direction. Less success has been obtained in breeding varieties resistant to insect attack, with a few notable exceptions, but there is a wide field to be explored here. With regard to protection against fungi, it is important for plant breeders and pathologists to co-operate, for many parasitic fungi exist in the form of different physiological races with diverse host relationships. This co-operation must continue indefinitely for it is known that these fungi occasionally mutate so that a variety of a crop plant hitherto resistant may become susceptible to a new race. The work of the plant breeder in this respect therefore rarely reaches finality. Again, breeding programmes for resistance to disease in the case of certain kinds of perennial plants may be very prolonged. For these reasons other methods of disease control should never be neglected.

New fungicides and insecticides of great potency have been discovered in recent years, and it can be confidently expected that others will become available. Novel methods of application of these substances have been introduced, and perhaps the day is not far distant when aeroplanes will be employed for their application under certain conditions. The nature of fungicidal and insecticidal action requires much further study, and in the latter field the research unit of insect physiology under the auspices of the Agricultural Research Council will be most helpful as well as in other fields under its survey. Many fungicides and insecticides at present cause phytocidal injury under certain conditions, the nature of which is not clearly understood. Here is a promising field for investigation by plant physiologists working in association with pathologists and entomologists.

Notwithstanding the efficacy of modern methods of seed disinfection for certain diseases a preferable means of control for some of these would be to ensure that the crops grown for seed are fully protected against disease.

The possibility of biological control of parasitic fungi and insect pests is a fascinating theme, but mention will only be made of some aspects that concern certain dangerous fungi which are root parasites. Much attention has been paid to these fungi in recent years, and it is now clear that some of them are only dangerous under certain conditions of the

original host or under particular soil conditions. For instance, when jungle is felled for establishing a tea plantation it has been shown that by ring-barking the trees before felling the roots are depleted of food reserves so that they are invaded by innocuous fungi instead of by the dangerous *Armillaria mellea* which otherwise spreads to the roots of the tea bushes. Much knowledge has now accrued about the interactions of micro-organisms in the soil ; many of these organisms secrete anti-biotic substances, some of which may inhibit the growth of dangerous fungi. Here is perhaps the most promising prospect for the further development of plant pathology and the control of some of the most dangerous diseases, for by encouraging the growth of the organisms which secrete these anti-biotics the dangerous parasites may be checked. Factors of competition also enter into the picture of soil micro-biological activity and there are glimmerings of the means by which the harmless saprophytes may be made to predominate.

A much neglected branch of plant pathology is the study of non-parasitic diseases. It is true that much attention has been paid to maladies induced by defective mineral nutrition, including deficiencies of trace elements, but there are many others associated with respiratory disturbances, abnormal water-relations, and so on, about which our knowledge is either meagre or non-existent. Physiologists and pathologists should co-operate in the study of these diseases.

Determination of the diseases caused by parasitic organisms and insects depends upon accurate diagnosis of the species concerned. In many groups of organisms taxonomy is still in a confused state, and much further provision of competent systematists is required who will study them not only in the laboratory, herbarium or museum, but also in the field. Many more students of plant viruses are also needed, especially for those which are causing concern in the tropics.

Genetics

No branch of science has contributed more to improved crop production during the last forty years or so than has genetics, for the discoveries of Mendel and others have provided plant breeders with basic principles for developing superior races of cultivated plants. Advantage of modern methods of plant breeding has been taken in practically every civilized community, although actual achievement varies greatly from country to country. There is, of course, still ample room for further progress by following breeding programmes upon what may be called orthodox lines, especially as regards the production of types resistant to disease. But pure genetical research as distinct from practical breeding programmes should be encouraged to the utmost for at any time fundamental discoveries may be made which may enable plant breeders to surmount present difficulties. Plant breeding may be defined as the acquirement of genotypes, specially adapted to particular environments, which will produce large yields of suitable quality. This involves both the creation of the genotypes and their maintenance. These two aspects will be briefly considered.

With regard to the production of specially desirable genotypes much more information is required about the inheritance of quantitative characters such as yield, plant height, weight of seed, etc., which are determined by polygenes. Closely related to this is the study of the effects

of in-breeding and cross-breeding in different crops with a view to determining how far the use of cross-bred seed, which has been so successful with maize, can be extended to other plants by using appropriate methods of pollination.

Mutations may be induced by a variety of agents, both physical and chemical. It appears that these induced mutations are like those which arise spontaneously and are mainly deleterious, but perhaps some of them could be used as a source of variability where the natural variability is slight. Looking to the future it may be possible to induce mutation in particular directions, and if that could be accomplished new vistas of progress would appear.

Colchicine, acenaphthene and other chemicals have attained great vogue for doubling the chromosome number, but their practical importance is probably limited to the induction of fertility in sterile F_1 hybrids. Much more information is required about the fertility and stability of these products. Another use for these substances is in the doubling of the chromosome numbers of the wild relatives of a crop plant of higher ploidy, thus facilitating the introduction of new genes.

In maintaining particular genotypes, where these are dependent upon sexual reproduction, purity of seed is of paramount importance. Much more work on the degree of isolation required for the maintenance of pure stocks, such as that begun at the John Innes Horticultural Institution, is needed, for only in a few plants is it known what the spatial range is over which cross-pollination of different varieties occurs.

Some workers advocate methods of seed reproduction in place of vegetative propagation for certain crops, e.g. raspberries, which are liable to rapid degeneration by viruses, although genetical methods would be needed to ensure that the seed was what it was intended to be. This could be combined with hybrid vigour by the use of self-sterile, cross-fertile parental stocks.

A special application of physiology to genetic problems is the need of methods to shorten the period between the seeding stage and reproductive maturity and of methods to secure overlap of the flowering period. Such methods would be particularly useful in the case of arborescent plants.

The maintenance of collections of living genetical material, both selected stocks and wild varieties and species, of all kinds of crop plants should be encouraged in different parts of the Empire. For instance, the Empire potato collection from South America will doubtless prove to be of inestimable benefit to the breeders of this crop. The preservation of such collections should be specially catered for since the labour involved in the maintenance of useful, though sometimes genetically troublesome, stocks can be very considerable.

Ecology

The study of the plant as a whole in relation to its environment and as a member of a community is now recognized as one of the most important aspects of botanical science. Knowledge of the integrated behaviour of the entire life of the plant is often deficient, even though particular facies of this life, e.g. photosynthesis, mineral nutrition, relation to parasites, etc., may have received much attention. Growing crops, whether herbaceous

or arborescent, are usually communities of more or less homogeneous populations, but the need for an ecological approach to their study should be emphasized. At present perhaps the forester recognizes the value of this attitude better than does the agriculturist.

The intensive study, from a comprehensive point of view, of individual species of particular communities, i.e. their autecology, has been fruitful in recent years in elucidating the relative success of certain species in different environments. Similarly, autecological studies of crop plants may be expected to lead to knowledge which will facilitate production of the maximum yield. Ecological investigations of this kind combine the separate techniques of the physiologist, the soil scientist and other specialists. It is in those parts of the Empire where intensive cropping is relatively new, and where wild or semi-wild plants are being grown, that studies of this kind are specially desirable. It is still uncertain whether it is really best to grow certain perennial economic plants in the tropics as pure stands or whether it would not be preferable in the long run to grow them as members of a mixed type of vegetation, more nearly simulating a natural community.

The grasslands of the tropics and the sub-tropics are immensely important and they certainly require much closer ecological study than they have yet received. As in temperate regions, superior strains of particular species may be discovered and exotic species may be introduced to certain regions, both of which may increase productivity. The question of grassland management concerns both plant ecology and animal husbandry.

The ecologist has important contributions to make in all matters concerning land utilization for agriculture, forestry, water-catchment areas and the like, especially where indigenous vegetation is to be replaced by crop cultivation. Researches on natural vegetation in relation to the underlying soil may often provide clues as to which kinds of land can be most effectively used for agriculture. As a preliminary to such investigations an ecological survey of the natural vegetation, aided by aerial photography, of areas into which agriculture is likely to extend would be of great service. All tropical lands under luxuriant high forest or secondary growth are not equally suitable for growing agricultural crops, and advice should be sought from the ecologist and soil scientist working in co-operation. Further study is also urgently needed of the best means of using or rehabilitating land in the tropics which has become wholly or partially derelict.

The assistance which ecologists can give in preventing or ameliorating soil erosion and degeneration is self-evident, and it is surprising that their aid has not more frequently been invoked. One can also point to the advantageous association of animal and plant ecologists in the control of certain insect pests as, e.g., in some of the tsetse-fly areas of tropical Africa, for in this way not inconsiderable tracts of land may be recovered for human habitation and cultivation. Lastly, it is perhaps not out of place here to stress the need for a comprehensive biological survey of tropical territories.

General considerations

In this brief survey indications have been given of directions in which botanical science may be expected to lead to improvements in crop produc-

tion. Detailed scientific analysis of plant functions is of great value but a synthetic approach to plant problems is also greatly to be desired. The various kinds of botanical specialists must co-operate for the solution of some of them, and the needs of plant and animal husbandry must be taken into consideration. It cannot be emphasized too strongly, however, that without the aid of specialists and without adequate attention to basic scientific principles progress will be disappointing.

Lastly, a plea may be made for the effective maintenance and further development of botanical gardens in different parts of the Empire. The importance and usefulness of the Royal Botanic Gardens, Kew, have been eloquently described by the present Director in a recent lecture to the Royal Society of Arts. Similarly, the other botanical gardens of the Empire are an immense asset. They should be used as centres of both fundamental and applied research ; furthermore one can never foretell when a particular plant is going to assume economic importance or when a species, hitherto obscure, is going to become of special interest for some kind of investigation or other. These gardens contain rich collections and they should be more adequately staffed than at present, with proper quotas of taxonomists and other experts.

The pioneer work of the Botanic Gardens at Peradeniya and Singapore in the exploitation of the *Hevea* rubber tree is eloquent testimony of the value of these institutions. Should not attention be given to the establishment of one or more botanic gardens in tropical Africa ?

(F. T. B.)

4. THE ANIMAL

The importance of a healthy livestock population throughout the world is fully appreciated in all responsible quarters. It may not be fully realized that in spite of recent developments in our knowledge of some of the essential matters pertaining to the maintenance of health, we are quite unacquainted with some of the processes and systems which have a vital bearing on the everyday life to which livestock is subjected. It is only within the past few years that attention has been directed to the use which can be made of fundamental scientific knowledge in the many problems of animal health. It is becoming abundantly clear that, without full consideration of the results of fundamental research in different branches of science, with a view to their application to animal health, we may fail to develop the livestock industry to the point at which there will be an abundance of animal products without maintenance of uneconomic numbers of animals. It should be the set purpose throughout the world so to maintain livestock that the minimum number will suffice for the feeding of the world's human population ; this can only be achieved if healthy livestock is available and if animal nutrition and husbandry are practised according to satisfactory, scientific and economic standards.

In considering animal health attention should be directed to the basic processes and systems concerned with the healthy animal body ; to conditions to which these processes and systems are subjected in the highly artificial life imposed upon livestock ; to problems of nutrition in different parts of the world, consequent upon the available types and supplies of

feeding materials and the possible deficiencies reflected in the health of the livestock ; to disease due to infectious and parasitic agents.

In all of these subjects fundamental scientific knowledge is essential ; it must, however, be ever kept in mind that such knowledge, while of far-reaching general importance, is to be looked upon by the veterinarian as a starting point in the translation of data to be applied to animal health. Even now we are making use of fundamental knowledge gleaned from different branches of science ; sometimes in its application to animal health problems it can be applied directly, on other occasions it has to be so altered that it fits into the picture we have to portray. Progress has certainly been made since the attention of workers in different branches of science has been given to agriculture, including animal health, and since those concerned with animal health problems have sought the collaboration of workers in other branches of science. In expansion of this work, however, the application of increasing knowledge has unceasingly to be kept in mind and for this purpose those conversant with animal health problems have to be vitally concerned.

Our knowledge of some of the basic processes of the animal body is sorely lacking. Attention need only be directed to the digestive system of the ruminant. We have a broad general knowledge of the processes which take place when food-stuffs of different kinds are fed to cattle and sheep but detailed information is lacking particularly on the part played by ruminal flora. Some progress has already been made by the combined studies of the anatomist, physiologist and biochemist and this work is a clear illustration of how the choosing of the results of the fundamental studies of a combination of workers is of valuable assistance in obtaining essential knowledge, leading to a better understanding of economic nutrition. It is vital that this type of work proceeds and that workers in the different branches of science are brought into such problems.

One of the outstanding subjects on which animal health depends under modern conditions of livestock management is the endocrine system. Here again, although considerable progress has been made we are grossly ignorant of the linkage between ' metabolic disorders ' and the action of this system. It is becoming very clear that animal health is dependent to a marked extent upon the ' health ' of the endocrine system and that the competent functioning of the animal body for present-day requirements of production is closely concerned with a stable endocrine balance. The demands made upon the milking cow, for example, are such that, unless we clearly appreciate and understand the part played by the endocrine system, we may fail in our attempts to produce milk and calves in the required amount and number to make dairy farming an economic proposition. In this respect we have to keep in mind that we are raising the milk output of cows to a figure far beyond that of the bovine female in the wild state and at the same time producing a calf each year. Milk production and calf breeding are closely related to an efficient endocrine system ; further fundamental knowledge on this system will enable us better to understand the requirements of the milking and breeding animals and will assist us in assessing in how far we can successfully ' force ' the cow to conform to modern economic requirements.

The successful breeding of animals is all-important for economic

production of animal products. Geneticists and workers in allied sciences must be encouraged to play a direct part in the study of the breeding of livestock, including poultry, again with a view to the development of stock of high economic value. The findings of fundamental research on species of animals other than farm livestock has an important bearing on the subject ; but such results can only form a basis and a guide for work on the specific economic animals concerned. In this category come studies of embryology ; we must know the stages of development of the embryo and foetus in order to provide the necessary nutrition for the female during pregnancy.

Nutrition of livestock has been studied for a long period and our knowledge of general principles is now extensive. We are now able to feed livestock on many different food-stuffs and to maintain them in a state of health and production. This, however, does not go far enough, for, although the mixture of substances in the diet of livestock probably supplies all the essentials for the maintenance of health we have but scanty information on the amounts of some of these essentials for both health and production purposes. Further, our knowledge of the metabolism of some of the essential elements is incomplete. The relationship of the soil, the produce of the soil (plants) and animal health, with regard to some of the minor (trace) elements is a study of paramount importance in agriculture. Workers in the different fundamental sciences are intimately concerned with this problem ; it is only by a combination of effort that a clearer conception of the subject will be forthcoming. We have already some information on the effects of deficiencies and excesses of some of the minor elements on animal health : cobalt and copper have been the subjects of some study ; other elements will have to receive attention. The group of workers on this subject must include personnel with training and experience in morbid histology and pathology as well as some with adequate clinical knowledge. Nutritional studies will have to embrace the feeding of pregnant livestock ; we have a number of recognizable, clinical diseases of livestock closely related to the nutritional status of the pregnant animal as well as diseases of the offspring traceable to deficiencies during pregnancy. The loss of young stock within days or weeks after birth may well depend on the nutrition of the mother before and after parturition ; the colostrum plays an important part, its study calls for the collaboration of fundamental scientific research from a variety of angles.

We have need for further information on the toxicology of various substances and of plants grazed by livestock ; there is still little definite knowledge on the subject. It is sometimes erroneously assumed, for example, that the finding of a given amount of a metal in an organ or tissue denotes that the animal concerned died as a result of having consumed a toxic dose. We need more information on toxic doses and the conditions under which various substances become toxic. With plants we require to know the conditions of growth, the period of growth, the conditions of the soil in which the plant was grown, etc., in order to appreciate fully their toxic qualities. This work can be carried out only by workers in the respective fundamental sciences before the results can be applied to animal health.

Diseases of livestock caused by bacteria, viruses and unicellular and

multicellular parasites are common in all countries; many have been and are being studied and methods of control are being evolved. In this work there is much to be obtained from fundamental scientific information, for the general principles of microbial invasion and control by immunological and pharmaceutical methods apply equally to animals and to man. Techniques for the study of bacteriology, protozoology and parasitology also have a common application. In all these studies fundamental scientific knowledge can be used to advantage.

The use of drugs and chemical preparations in the treatment and control of diseases in livestock has come into operation to a marked degree; sulphonamides and penicillin have been shown to be of much value in animal work. There is room for expansion in this type of study; it can be accomplished only by full collaboration with chemists, biochemists and pharmacologists.

In our studies of the control of external parasites of livestock the emulsification of the lethal agent is an important feature as well as physical features of wool and hair which determine the penetration of the parasiticide. Physicists are of much assistance in working out methods and techniques.

The housing of livestock requires full and detailed study; accurate knowledge of the air space requirements, types of buildings, etc., is fundamental to healthy animals. In this work there is scope for the collaboration of workers in the different sciences and for the application of results of concerted efforts.

This short note may suffice to outline the necessity for the making of full use of fundamental scientific knowledge in our attempts to maintain and improve upon animal health, bearing in mind the artificial conditions under which livestock are kept for economic purposes; further, it is to be borne in mind that the application of such knowledge may vary with the types of animals and the conditions under which they are used in different parts of the world.

(T. D.)

PROBLEMS IN AGRICULTURAL SCIENCE IN AUSTRALIA: ANIMAL PROBLEMS—THE ANIMAL INDUSTRY

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ANIMAL PRODUCTION

AUSTRALIA lies approximately between latitude 10° and 44° South. All species of domestic animals are exotic to Australia. North of the tropic of Capricorn the main producing animals are beef cattle, with some goats for domestic purposes, but there are also merino sheep and some dairy cattle. Below the tropic of Capricorn the usual farm animals are represented but merino sheep predominate, and wool production is the largest branch of the industry. The Australian merino parent studs are of three main types, viz., the fine-wool type, which is predominantly Saxon in origin, the medium fine-wool type, which has developed from the Peppin strain, and the strong-wool type originating from South Australian strains. The medium and the strong-wool types have been evolved in Australia to suit the several climatic environments. The Corriedale, a Lincoln-merino half-bred, is gradually gaining in popularity as a dual purpose sheep in the higher rainfall temperate regions. The merino ewe at any age, but usually when cast for age as a wool-producer, is crossed with one of the British long-wools, notably the Border Leicester, to provide cross-breds as mothers for the first quality lambs for meat production from matings with Southdown or other approved sires. Lamb and mutton production is mainly confined to the higher rainfall or irrigation areas, production of cross-bred ewes to the marginal areas, and wool production to the marginal and lower rainfall areas. The primary problem of the producer is to fit the sheep and the type of production into the appropriate environment. This has occupied the attention of sheep breeders from the earliest days of development of the continent but there has been little or no assistance from science. Scientific animal breeding can do much to improve and to fix types. In general there is too much variation in flocks even after 30 per cent of the ewes have been culled before reaching maturity. Scientific study of the environment—climate, soil and plant associations—and of the physiological adaptations of the animals including study of the effect on the product, wool and meat for example, are also called for.

Similar problems in animal breeding and in the evolution of most suitable types to fit particular environments exist in the beef cattle and dairy cattle branches of the industry. Hybridization with selected exotic tropical strains of cattle requires careful and detailed scientific study.

There are other background scientific problems of the grazing industry.

There are some specific enzootic diseases of sheep and cattle calling for study of the soil, and of the plant and the animal associations. Some are due to specific mineral deficiencies but others appear to be more complex.

Over all is the problem of variability in rainfall and the resulting periods of shortage of food-stuffs. Improvement in husbandry methods can meet this difficulty only up to a point. The problem is not simple but many branches of applied science can improve knowledge and thus bring a greater measure of control. Conservation of water and of fodder are full of problems which call for scientific investigation. The special nutritive value of specific fodders calls for particular study in relation to general health and to the particular product to be produced, such as wool, milk and meat. Especially in the lower rainfall areas some pooling of natural resources seems to be called for if periods of drought are to be provided against. This would call for some degree of regional planning. By the use of scientific methods in the study of the grazing habits of animals and of pasture plants under grazing, a more accurate assessment of the carrying capacity of pastures, and of natural pastures in particular, can be made.

In the higher rainfall areas natural pastures can be replaced by improved pastures and the carrying capacity can be thus increased. As the first limiting factor is the low nitrogen level in the soil, leguminous plants are grown with the aid of phosphatic dressings to raise it and to enable grasses to be established. In some instances this has led to the occurrence of new animal diseases. Notwithstanding the raising of the general nutritive level of the animal by these means there may be a decline in fertility. At present a very serious position has developed in Western Australia where sheep grazed exclusively or almost exclusively on an early strain of subterranean clover have developed a catastrophic fall in fertility and have shown certain specific uterine abnormalities. These problems call for more detailed knowledge of sex physiology of the animal and more knowledge of plant physiology as well as physiological and toxicological investigations of plant material. Improved pastures have also increased the incidence of entero-toxaemia of sheep which, although having been brought under a measure of control by prophylactic vaccination, still calls for scientific study.

The problems briefly indicated are those associated with the grazing animal. In those branches of the industry in which the animal is not kept on pasture, as in the pig and poultry branches, the problems are similar to, if not identical with, those in most other countries. The general mildness of the climate in Australia excludes the necessity for complete housing and for artificial heat in the winter. There is thus no absence of natural, unfiltered sunlight. Production problems call for scientific investigation of breeding systems. The successful feeding of these animals calls for adequate supplies of protein at reasonable cost.

ANIMAL DISEASE

Animal diseases in Australia may be divided into three main types, viz : (1) environmental and non-infectious, (2) those produced directly or indirectly by infective agents which are commensal or semi-commensal in character, and (3) those infectious and parasitic diseases which are contagious or transmissible.

1. Environmental and non-infectious diseases

Many of these are commonly called nutritional diseases and are characterized by some degree of malnutrition. They are usually found in fairly well-defined areas and are often associated with definite soil types. Among these we have mineral deficiencies such as copper deficiency and cobalt deficiency of sheep and cattle. The pathology of these diseases is incompletely studied. Their extent is not fully determined. Frank deficiencies are more or less easily recognized but relative deficiencies are often seasonal and irregular in occurrence, are difficult to recognize and require extended study. Frank phosphorus deficiency does not appear to occur in sheep but in phosphorus-deficient areas the nutritive value of the pastures is low and malnutrition in the sheep is common. In these deficient areas cattle show a frank deficiency of phosphorus and benefit from the administration of inorganic phosphorus. Disturbances of calcium metabolism occur in sheep, cattle and horses. Just how far these are due to deficiency of calcium in the diet has yet to be determined but horses certainly benefit from a higher calcium intake or calcium supplement to the diet.

More intensive study of mineral metabolism and of mineral imbalance is required. Copper deficiency, for example, may occur when the copper intake is normal but the intake of molybdenum is abnormally high, and relatively low copper intake may be intensified into an absolute deficiency when the intake of calcium and of other elements is abnormally high. So-called mineral deficiencies might in some instances, at least, be regarded more correctly as disturbances of mineral balance. The sheep appears to be very susceptible to changes in the copper intake or to deficiencies and excess of other elements which raise or lower the availability of copper. Copper poisoning is enzootic in Australia in certain areas, on the one hand when the soil derives from copper-bearing rock and on the other hand on certain soils with normal copper content but which are responsible for some mineral imbalance through the plant. These disturbances of mineral balance and resulting toxicoses call for careful scientific investigation. We may place plant poisoning of stock in this group of environmental diseases. There is much interesting and valuable work to be done in this field although knowledge of the toxic principle and of its action on the animal have not brought losses of stock from these causes under effective control.

The use of introduced exotic plants for the improvement of pastures has introduced new problems. The most serious of these is the reduction of fertility of sheep, on certain clover dominant pastures, which has already been mentioned.

2. Infective diseases due directly or indirectly to commensal and semi-commensal organisms

We might class the diseases due to the genus Clostridium in this group. They have caused severe losses, particularly of sheep. 'Black disease,' 'blackleg,' entero-toxaemia, tetanus and 'swelled head' in rams are examples. For the most part they have been brought under control, but prophylactic measures must be continued if break-downs are to be avoided.

There seems to be little prospect of eradicating the diseases as is possible in most of the contagious or transmissible diseases. Botulism, which is a true toxaemia, also comes into this group though indirectly, and is also brought under effective control by prophylactic vaccination.

Caseous lymphadenitis of sheep, which is not usually transmissible by natural means, has not been brought under effective control. Improved husbandry methods will reduce the incidence but the problem of effective control remains unsolved. It seems possible that swine erysipelas is also a disease belonging to this group and that a better understanding of the environmental factors favouring its occurrence would lead to a satisfactory control. In both these diseases modification of the soil by the animal through its excreta favour the multiplication of the causal bacteria in the soil. On present knowledge it seems justifiable to place bovine mastitis in this group. Many of the infections of the udder are by frankly commensal bacteria, such as the micrococcus, *Cl. welchii*, *Str. faecalis* and the coliform bacilli, whereas the more common infections, those due to the staphylococcus and *Str. agalactiae*, are produced by commensal organisms that are acquiring parasitic habits. Eradication of this disease by the classical methods applied to contagious diseases caused by strict parasites is, therefore, not likely to be generally successful. Scientific investigation is giving a reasonably good picture of the disease and its epidemiology which shows the way to control methods. The lack of technical training of the producer presents the most difficult aspect of the problem and limits the application of effective control methods.

3. Transmissible contagious and parasitic diseases

In this group of diseases the causal agent has become a true parasite. The domestic animals in Australia are free from many of the serious plagues present in other countries.

Cattle. Contagious pleuro-pneumonia of cattle has been eradicated from the more settled parts of the continent but is enzootic in the larger cattle herds of Northern Australia. The traffic southwards of cattle being moved to fattening areas sometimes leads to fresh outbreaks of the disease in the more closely settled areas. Eradication is made possible by the detection of carriers by the complement fixation test. Vaccination by a live culture vaccine gives a high measure of protection. However, in those northern cattle stations which are very remote from laboratories and on which complete musters of the cattle are impracticable, eradication of the disease would appear to be unattainable.

Tuberculosis of dairy cattle has been kept in check for many years and its eradication from closed herds is usually comparatively simple. As diagnosis depends upon the tuberculin test, the loss of sensitivity in some cases of chronic tuberculosis is responsible for difficulties of eradication from time to time. A supplementary method of diagnosis, such as a complement fixation test, is called for.

Brucellosis, especially of dairy-cattle, is very widespread and causes great economic loss. The classical methods of eradication are often unsuccessful. Prophylactic vaccination appears to have definite value especially when the incidence of infection in the herd is high. It can be used to give immediate results in reducing wastage and to prepare the

way for a more economic and conservative application of classical methods of eradication. The problem calls for intensive immunological studies. Anthrax occurs in restricted enzootic areas but by the adoption of strict sanitary methods and prophylactic vaccination, the disease is kept under reasonable control. Salmonellosis of calves and adults is troublesome in some areas.

The cattle tick, *Boophilus microplus*, is widespread in the summer rainfall areas especially on the eastern coastal borders. In most of these areas periodical dipping is used to reduce the tick populations on the host, but no attempt is made at eradication except in the south-eastern margin of the area. In addition to the tick worry, produced when the infestations are heavy, the tick spreads the protozoan parasites which produce the tick fevers. In Australia these are three in number, viz. : *Anaplasma marginale, Piroplasma bigeminum* and *Babesiella argentina*. The cattle become infected in calfhood and become pre-immunized. The introduction of 'clean' susceptible cattle into the tick areas is precarious, and artificial prophylactic vaccination has to be applied. After years of use of the arsenical dip to control tick populations on the host there is evidence to suggest that strains of ticks have evolved which show a relative resistance to arsenic. Eradication of the tick is the ideal but this is impracticable under the present conditions. Toxicological studies are called for with the object of evolving more efficient tick killing methods.

The buffalo fly, *Lyperosia exigua*, existed in the Northern Territory for many years and during the wet season extended in all possible directions, but this extension eastward was checked each time by the existence of more arid areas. Eventually, under conditions more favourable to its spread, it broke this natural barrier and found its way to the east and extended south along the coastal area. No artificial means have been found of preventing the spread of this insect through climatic zones that are favourable to it. The newer insecticides and traps have been found to give a measure of control in dairy herds but the methods are inapplicable in the larger beef cattle herds. The problems calls for continued biological and toxicological investigation.

Internal helminth parasites cause serious losses in calves especially in the coastal areas in the tropics, but also in the temperate regions. The use of anthelmintics offers the main means of alleviation but there is room for much study with a view to finding the weak spots in the metabolism and in the life history of the parasite, and to finding more selective and toxic anthelmintics. The control of hydatid disease and liver fluke disease offers a problem and calls for constant vigilance in some districts.

Sheep. There are no serious contagious diseases of sheep in Australia. Contagious foot-rot is probably the most troublesome. In the higher rainfall areas and in the presence of denser sheep populations, endoparasitic infestations constitute a serious problem. The helminth parasites may be divided into two main classes, viz. : those favoured by summer rainfall and those favoured by a winter rainfall, although in many districts both classes exist and with fluctuation in rainfall incidence one or other may become dominant. Oesophagostomiasis has proved to be the most difficult helminth infestation to control in the summer rainfall areas. Phenothiazine has proved a useful anthelmintic, but without nutritious grazing in the

winter months, especially for lambs and weaners, control has remained inadequate. Eradication of these helminth parasites appears to be impracticable in the present state of knowledge, but by the use of anthelmintics at critical times determined by epidemiological considerations, and by the maintenance of a reasonably high plane of nutrition, a fairly satisfactory measure of control can be attained. However, these methods call for unending attention and vigilance. A greater knowledge of the physiology and metabolism of the helminth is called for and is expected to lead to a soundly based method of attack by more effective anthelmintics.

Of the ecto-parasites, the sheep ked and the louse are widespread in the higher rainfall areas. They are kept under control by a single, annual dipping. Eradication is practicable in closed flocks and when traffic and exchange are reduced to a minimum. The newer insecticides may increase the efficiency of the dips but cost may prove a limiting factor to their general use. Sheep scab was eradicated from New South Wales by 1868 and from Western Australia by 1895. Recently a new mite parasite, *Psorergates ovis*, has been found in scattered areas. Its occurrence is somewhat insidious but once diagnosis is established it can be effectively eradicated by the use of a polysulphide dip.

The ecto-parasite which has caused the most widespread problem especially in merino sheep is the so-called sheep blowfly, *Lucilia cuprina*. Although a facultative parasite, it seems to have developed a stronger degree of parasitism during the last forty years. There is evidence to suggest that the natural fly population derives mainly from strike of the living animal rather than from carrion. There is a large measure of biological control of the Lucilia population breeding on carrion by the carnivorous maggots of the so-called secondary flies. Control of the Lucilia population by traps and other artificial means does not appear to be practicable. The sheep is struck in the region of the breech in the vast majority of strikes. The predisposition is determined by the skin conformation and by the ' excessive ' amount of wool developed on the highly selected sheep. These favour the soiling of the parts by urine and the retention of moisture which in itself is essential for a strike to become effective. These predisposing factors can be eliminated by means of a plastic operation involving the removal of a pattern of skin from the breech and by leaving the tail long enough to reach the tip of the vulva. By these means the sheep can be protected for life. Body strike is a problem which has not been solved. It occurs irregularly and depends on excessive moisture of the fleece when monsoonal rains fall over an extended period. The use of D.D.T. at critical times may possibly prove effective in preventing a ' strike wave.'

Swine. In the absence of swine fever there is no really serious contagious disease of swine in Australia. Brucellosis although present has not become extensive in occurrence. Tuberculosis due to the bovine bacillus still occurs but probably is rarely transmitted from pig to pig. Tuberculosis due to the avian bacillus is present and can become a menace. A form of infectious pneumonia is present but the etiology is undetermined. Necrotic enteritis and more especially swine dysentery cause severe losses at times but their etiology is still undetermined. Many of the infectious diseases of swine are ill-understood. Although classed as contagious diseases some of

them would appear to be more correctly classed as environmental diseases, due to semi-commensal organisms. Swine erysipelas, for example, seems to result from the building up of the population of the ubiquitous Erysipelothrix, through the modification of the soil by the excreta of the animals, associated with the exaltation of pathogenicity by repeated passage through the animal. When the nutritional husbandry and hygienic methods are poor these swine diseases cause heavy losses. There is room for much scientific research to increase our knowledge of a very interesting group of diseases.

Poultry. There are many contagious diseases of poultry in Australia and enteric parasitism is evident. In no instance is there a problem peculiar to Australia. The most troublesome diseases are as follows :—infectious laryngotracheitis, fowl pox, pullorum disease (salmonellosis), spirochaetosis, avian tuberculosis, coccidiosis and helminthiosis due to Ascaris and the tapeworms. On the modern poultry farm these diseases can be kept under reasonable control. In the barn-yard the problem cannot be met adequately.

Exotic diseases of animals

All the contagious diseases of domestic stock in Australia have been introduced, as have the animals, from other countries. The distance from exporting countries and the long sea voyage have formed an effective barrier against the importation of most of the more serious plagues. However, Australia exists in constant danger of the introduction of serious exotic diseases. With increase in the speed of transport the danger is becoming greater. The greatest danger is usually not from the introduction of the live animal but from that of animal products and litter. Swine fever has been introduced several times, Newcastle disease of fowls twice, surra once, and rinderpest once. All have been conquered and eradicated. Three-day sickness has been introduced but has remained unconquered. Rabies, foot-and-mouth disease and other more serious plagues have been kept out. With increasing knowledge gained by scientific research, the protection against these diseases can be increased. Improved diagnostic methods of bacterial, protozoal and viral diseases are required and advancement in the evolution of chemotherapeutic substances will add an additional safeguard.

Every branch of science, background and applied, is called on to play its part in the advancement of knowledge which will help to solve or eliminate the production and disease problems of the animal industry.

ANIMAL HUSBANDRY IN EAST AFRICA IN RELATION TO HUMAN FOOD PRODUCTION

By R. DAUBNEY, C.M.G., O.B.E.

ETHNICALLY the natives of East Africa fall into two main groups, the Bantu and the Hamitic. Both keep livestock, but as a broad generalization one can say that the leaning of the Bantu is towards cultivation, and that of the Hamitic peoples towards pastoral pursuits, and that in the course of time there has developed a segregation of these peoples on the areas of land suited to their respective pursuits. Bantu people, such as the Kikuyu, cultivate what were once the most fertile and well-watered lands of East Africa, while the Masai and other pastoral tribes live a semi-nomadic life on undeveloped ranching lands of low stock carrying capacity.

On the richer arable lands of the agricultural tribes subsistence farming was formerly practised, but during the late twenties and early thirties of this century a Government drive for the production of cash crops brought almost every acre of arable land in these reserves under the plough. Cultivation and the management of livestock have never been in any way associated in the minds of the agricultural tribes; and until small bush dairies were established for the preparation of ghee the sole cash return from stock was derived from the very occasional sale of a steer or heifer, and their sole contribution to the peasants' diet a little milk that was inefficiently extracted with one hand from any cow that happened to be suckling a surviving calf. The calf mortality from enzootic tick-borne diseases in these areas ranges from 45 to 75 per cent per annum, and those cows whose calves die dry off immediately. The livestock congregate daily on the communal grazing grounds which from 1930 onwards have consisted merely of such areas as are too poor or otherwise unfit for cultivation.

In the pastoral reserves a seasonal migration is practised by the stock-owners, the seasonal use of grazing areas being dictated by their dependence on temporary or permanent water supplies. The rotation cannot be varied, and when failure of the rains compels the stock to remain throughout the season on the permanently watered areas great damage is caused through trampling and overgrazing. All stock are shut up at night to protect them from attacks by wild carnivores.

The pastoral and agricultural tribes have of necessity a different dietary: the Masai for example subsist mainly on blood, milk and meat, rich in first-class protein, fats, vitamins A and B, iron and calcium; while the natural vegetarian diet of the Kikuyu is deficient in protein, fats, iron and calcium.

It is in the more densely populated agricultural reserves that education has made the greatest progress, and these are the tribes that have furnished

most of the wage-earning labour outside the reserves, whether on farms or in Government or other offices. They have also supplied the majority of recruits for the armed forces.

Since the taste for a more varied diet, including meat and fats, is rapidly acquired in the course of ordinary civil employment, it is probable that experience of the advanced diet given to the African askari will lead to a very early change in the dietary habits of the agricultural tribes. Indeed, nothing is more certain than that the desire of the agricultural tribes for an improved dietary will outstrip their ability to produce the necessary foodstuffs; for inefficiency is the most striking characteristic of native farming methods whether in crop or animal husbandry. The fertility of arable lands in the native reserves has been run down, soil structure has been lost through excessive cropping and bare fallows which expose the soil to the weather, and it can only be restored through the use of grass leys and the grazing animal. A conservative system of mixed farming is the only possible solution for the agricultural reserves, and this means control of the enzootic tick-borne diseases through universal dipping, disease control generally and the provision of a zebu dairy cow capable of giving an economic return. To-day these are our main objectives in Kenya.

The pastoralist is no more efficient as a producer. For example, 50,000 Masai owning 720,000 head of cattle can apparently contribute no more than 20,000 to 22,000 head of slaughter cattle per annum towards feeding the population of Kenya, representing an annual increase of something under 3 per cent. Compare this with the Australian slaughterings of 16 to 19 per cent from $12\frac{1}{4}$ million cattle—including 25 per cent of dairy cows—in 1931, and one begins to understand why it is that East Africa is in danger of failing to produce sufficient food to maintain even present dietary standards in the near future.

Without an efficient livestock industry in both pastoral and agricultural areas dietary improvement is an impossibility, and this basic fact is only now being recognized by governments. The livestock industry must furnish the first-class biological protein, calcium, animal fats and some vitamins of the B group. Indirectly, through the medium of grass leys and manuring it must contribute fertility, and so make possible conservative systems of agriculture far more productive than any that obtain in East Africa to-day—and which are at the same time systems that will not rob the land and lead to soil erosion, poverty and famine, those inevitable *sequelae* with which we, in Africa, are so familiar to-day.

BRIEF OUTLINE OF THE PASTURE PROBLEMS IN AUSTRALIA

By J. G. Davies
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For simplicity of presentation, the pasture problems may be grouped on a geographical basis.

THE COASTAL BELT CONSISTING OF THE DAIRYING AREAS OF AUSTRALIA

(*a*) Deficiencies of both major and trace elements on the lateritic soils of the sub-littoral of Western Australia and South Australia. These deficiencies are even more acute on the aeolian calcareous sands of the immediate littoral. In Western Australia the satisfactory stands of *Trifolium subterraneum* resulting from the use of phosphatic fertilizers, and in some areas copper salts, cannot be fully exploited because the perennial grasses fail to persist, though heavy growth of the less satisfactory volunteer annual species of *Bromus* spp., *Vulpia* spp. and *Hordeum* spp. is characteristically to be expected. The factors militating against the persistence of the perennial grasses are not understood, but poor aeration of the soils during the wet winter months must result in lowering of the available nitrogen and militate against the deep rooting necessary for survival through the short arid summer period. High chloride content of the subsoil is suspected under similar conditions on Kangaroo Island in South Australia.

Substantial areas of undeveloped lands are found throughout the coastal belt of New South Wales, and particularly in Queensland, and the recent successful development in Western Australia and South Australia following the use of copper suggests that trace element deficiency is an important factor in the lack of development of these well watered but infertile soils.

(*b*) The improved dairying pastures of the coastal areas and of the cleared, wet, sclerophyll forests adjacent thereto present no important problems other than the better design of crop rotation and fuller utilization of fodder resources by conservation. Recent advances in mechanization, especially the advent of the pick-up baler, should improve this position.

(*c*) Certain areas of ferruginous soils met with in the Gippsland district of Victoria, near Robertson in New South Wales, and on the Dorrigo Plateau of New South Wales, present difficult problems in pasture establishment, particularly of pasture legumes. These soils appear to fix phosphates, though the evidence is inconclusive. In at least one instance, a pasture of the deep-rooted perennial *Phalaris tuberosa* in admixture with *Trifolium subterraneum* has been successfully maintained in a highly productive state for six years by the combined use of calcium hydroxide and superphosphate.

(*d*) The natural pastures of the tablelands of New South Wales present a number of difficulties. Soils are generally acidic, and are derived from granites or old sedimentary rocks. On the New England Tableland, serious difficulties are encountered in sheep rearing—losses in the weaner stage being of the order of 20–30 per cent. This loss is primarily due to a dietary low in protein and minerals supplied by the endemic pastures.

THE SEMI-ARID AND ARID PASTORAL AREAS OF THE INTERIOR

In the south these are primarily used for the grazing of the Merino sheep, but in Queensland cattle displace sheep, especially in the far interior.

The main problem is the development of a grazing technique which will remove the element of exploitative grazing now existing. This involves, also, the revegetation of eroded lands and the rehabilitation of pastures degraded by over-grazing. Little effort has been directed towards using the endemic grasses and herbage plants. The study of the selected endemic species within such genera as *Danthonia*, *Stipa*, *Eragrostis*, *Panicum*, *Digitaria*, *Paspalidium*, *Eriachne*, etc., is called for. Some attention has been given at the Waite Agricultural Research Institute, and more recently by the Division of Plant Industry, to the *Danthonia* species, whilst a considerable body of information is available on the Chenipodiaceous genera—*Atriplex*, *Kochia* and *Rhagodia*—both from South Australia and New South Wales. The technique of seed harvesting and of saving these endemic species is an important practical problem, whilst the study of their ecology and life history, followed by development of élite strains, should materially enlarge the extremely narrow range of Australian sown pasture species.

THE HIGH RAINFALL COASTAL BELT OF NORTH-EAST QUEENSLAND

The main crop in this area is sugar-cane. The problems associated with the development of improved varieties of high sugar content, crop rotation, weed control and manuring, are the function of the Bureau of Sugar Experiment Stations of the Queensland Department of Agriculture.

The development of pastures for dairying and for beef fattening in these areas is difficult because of the absence of suitable legumes. Recent work at the Bureau of Tropical Agriculture, South Johnstone, indicates that certain of the tropical legumes such as *Centrospenna* and *Pueraria* may be capable of exploitation in admixture with such tropical grasses as *Panicum maximum* Jacq. and *Melinis minutiflora* Beauv. On the adjacent Atherton Tableland, *Paspalum dilatatum* Poir. forms almost pure swards with an ephemeral growth of white clover, *Trifolium repens* L., in the spring months. The deterioration in yield and carrying capacity of these dairying pastures is causing concern.

NORTHERN AUSTRALIA

This zone includes the Kimberleys of Western Australia, the Northern Territory and the basin of the Gulf of Carpentaria in Queensland. It is

now used for beef cattle raising. The problems here include the development of the pastoral cattle industry and general agriculture on the infertile soils of the monsoonal areas. The definition of the existing resources is incomplete, but recent experience of the Australian military forces and of the Department of Agriculture of Western Australia suggests that a wide range of agricultural and horticultural crops can be grown on the alluvial soils of the river valleys when the short summer rainfall season is supplemented by irrigation. Further studies of pastures and crops under irrigation and dryland conditions are being instituted by co-operative effort of the Western Australian Department of Agriculture and the Council for Scientific and Industrial Research on the Ord River in the Kimberleys, and by the latter at Katherine in the Northern Territory. These two agricultural experimental field stations will be the bases from which a complete resources survey of the two regions will be made, later to be extended to the Gulf of Carpentaria basin of Queensland.

IRRIGATED PASTURES

The newly opened irrigated lands of the Murray-Murrumbidgee valleys present a number of problems associated with the establishment of pastures. The soils of the Western Riverina are heavy grey soils of low organic matter content and of low water penetration due to high dispersible clay content. The use of preconditioning cereal crops—winter cereals and rice—the development of appropriate cultural operations, the selection of suitable pasture mixtures and the design of new irrigation techniques and practices are necessary for the successful use of these heavy soils.

These newer areas also present a problem in farm management; for only a proportion—from one-fourth to one-tenth—of each farm holding is commanded by irrigation water, and the successful use of both the irrigated and dryland portions (the latter of low carrying capacity, from one sheep to two to one sheep to five acres) requires a careful technique to avoid severe over-grazing of the dryland areas.

GENERAL

Noxious Weed Control

A number of weed pests exists on the grazing lands. The most serious are :—

Bassia Birchii F. Muell—Galvanized Burr. This species is the only endemic species of Australia that has become a major pest. During the past fifteen years it has progressively occupied the red sandy loam soils of southern Queensland and northern New South Wales. Studies of the species are, as yet, limited to the field because it has not yet been possible to germinate the seed under artificial conditions. Adjustment of grazing intensity has not given good results over a period of eight years, though lighter stocking has resulted in increasing density and yield of the associated endemic grasses.

Xanthium spinosum L.—Bathurst Burr—is a widespread pest in Queensland, New South Wales and South Australia.

Xanthium pungens Wallr.—Noogoora Burr—is a pest of river flood plains in Queensland and northern New South Wales. The present method of dealing with these pests is hand cutting, a laborious and ineffective method.

Pteridium acquilinum (L.) Kuhn—Bracken Fern—is a pest of cleared forest lands in southern New South Wales, Victoria, Tasmania and, to some extent, South Australia.

Rubus fruticosus L.—Blackberry—is a pest of fertile soils in the better rainfall areas of southern Australia. Its control in gullies and declivities is extremely difficult.

Homeria collina (Thunb.) Vent. and *Homeria miniata* Sweet—the one- and two-leaved Cape Tulips—are widely distributed in the better watered districts of Western Australia, South Australia and Victoria. Some centres of infection exist in New South Wales.

Other weeds of pastures include *Emex australis* Steinh., on sandy soils in Western Australia ; *Erodium botrys* (Cav.) Bertol., in Western Australia ; *Asphodelus fistulosus* L., in the Murray mallee of Victoria ; and *Aristida leptopoda* Benth., the white spear grass of the north central Queensland self-mulching basaltic soils.

The four serious weeds of cultivation are :—

Lepidium Draba L.—Hoary Cress—mainly in the Victorian Wimmera district, but present elsewhere on wheatlands in Victoria and in South Australia and New South Wales.

Chondrilla juncea L.—Skeleton Weed—an extremely serious pest of the wheatlands of the Eastern Riverina of New South Wales.

Cyperus rotundus L.—Nutgrass of the rich coastal lands in New South Wales and Queensland.

Sulvia reflexa Hornem.—Mintweed—on the black earths of the Darling Downs in Queensland.

More information is required on the physiology and ecological relationships of these plants and on the factors that enable them to compete successfully under present agricultural regimes.

The commoner weedicides (arsenates and chlorates) have been extensively and unsuccessfully tried, but with uniform lack of success. In practically every instance the weed is the last survivor.

Experiments are now in progress to test the value of the newer phenoxyacetic acid derivatives, and the differential response of species to these hormone-like substances should provide more satisfactory weedicides than have been hitherto available. Plant competition is the most hopeful control method, and it has been successfully used in the control of *Hypericum perforatum* L. var. *angustifolium* D.C., St John's Wort, on the south-eastern highlands. Pastures of *Trifolium subterraneum* L., with and without *Phalaris tuberosa*, adequately fertilized and managed, give complete control of this weed. Control by insect parasites, so successfully exploited with Prickly Pear, *Opuntia* spp., is also successful with St John's Wort and partially successful with *Lantana Camara* L., Lantana. The search for insect parasites will continue.

A problem closely allied to weed control is that of the regeneration of

elements of the climax vegetation on the ringbarked cattle country of Queensland. Practically the whole area is tropical and sub-tropical savannah woodland. This regeneration is from both root suckers and seedlings. The low productivity and carrying capacity of these areas (one cattle beast to 10 to 30 acres) present a marked economic bar. The factors that make for this regeneration are not at all understood. The regeneration is sporadic. Practically all the endemic eucalypts and some of the Angophora species cause trouble in various localities. The aggregate areas involved are very large, extending from the Maranoa district to as far north as Hughenden.

SELECTION AND BREEDING OF STRAINS OF PASTURE PLANTS

A number of valuable ecotypes of certain important pasture species has been recognized, isolated and developed in Australia. These include 'Hunter Valley' Lucern; the Clunes, Colac and Kyneton strains of Perennial Ryegrass; *Phalaris tuberosa* is, itself, a broad ecotype; the 'Dingee' Irrigation White Clover; a wide range of strains of subterranean clover has developed in various localities including the early flowering strain 'Dwalganup' in Western Australia, the late flowering 'Tallarook' strain in the Goulburn Valley. Other strains of distinctive agronomic characteristics are 'Bacchus Marsh' from Victoria, 'Mulwala' from the Murray Valley, 'Wenigup' from Western Australia. One of the most interesting strains is the recently recognized 'Riegelt's White Seeded' or 'Yarloop' strain from Harvey in Western Australia. This strain will stand lagoonal conditions during the winter months, and its use will enable the development of pastures on the coastal swamp lands in that State.

Wimmera ryegrass has been intensively studied and distinctive strains developed in Victoria, New South Wales and Western Australia. The aim in the last two instances was the production of early flowering strains. Very promising results were being obtained in 1939.

Improved strains of *Phalaris tuberosa* and of *Trifolium fragiferum* had been successfully developed at the Waite Agricultural Research Institute.

The programme of strain building, both by selection and breeding, was interrupted at the outbreak of the war, and for the past four years scarcely any advance has been possible. The basic material has been carefully preserved and the programme will be steadily resumed. Plant selection and improvement will have to be applied to the endemic species, for a wealth of material as yet untapped awaits the plant breeder.

A SURVEY OF THE MAIN PROBLEMS IN AGRICULTURAL SCIENCE AND ITS APPLICATION TO VARIOUS PARTS OF THE EMPIRE

By F. J. FILMER, D.V.Sc., W. M. HAMILTON, M.Agr.Sc., D.Sc.(N.Z.) and P. W. SMALLFIELD, M.Agr.Sc.

THE total area of New Zealand is approximately 66 million acres of which 43 million acres are occupied. The remaining area of 23 million acres includes rivers, lakes, roads, forest reserves and mountainous areas, etc., unfit for settlement. The occupied area consists of :—

	acres	per cent
sown pasture land	17,489,548	40·69
field crops	1,250,426	2·91
fallow	110,000	·26
orchards	19,196	·04
plantations	859,737	2·00
other cultivated land	101,093	·24
total area cultivated	19,830,000	46·14
tussock or other native grassland	13,869,330	32·27
forest	2,885,884	6·71
other unimproved areas	6,393,096	14·88
total area unimproved	23,148,310	53·86
total area occupied	42,978,310	100·00

Sown and native grasslands comprise 73 per cent of the total occupied area, while forest, plantations and unproductive areas comprise 23·6 per cent, leaving only 3·4 per cent of the occupied area for crops, orchards, etc.

New Zealand farming is therefore dominantly pastoral. The average gross value of farm production in the three seasons 1939/40 to 1941/42 was £90 million of which 90·8 per cent was derived from livestock products, 5·5 per cent from arable cash crops and 3·7 per cent from orchards, market-gardens, tobacco, etc. The dominant livestock industries (dairying, sheep and beef cattle) are almost wholly dependent on pasture production, and the types of farming practised are intimately related to the type and productivity of pasture sward which can be economically maintained on any given class of country. In the drier areas of the South Island pastures are supplemented by crops for autumn fattening of lambs, and winter maintenance ; in the North Island reliance is placed on pasture growth

supplemented by hay and silage conserved from the surplus spring pasture growth aided by a small and declining amount of cropping.

Annual production from pastures varies widely according to soil fertility (natural or induced), climate, topography and management. On well-managed swards, however, a dry matter production of 11,000 lb. per acre seems from experimental evidence to be a reasonable target in areas of well-distributed rainfall. Assuming complete utilization, Jersey cows producing 300 lb. fat per cow (with necessary replacement young-stock) could theoretically produce 420 lb. of butterfat per acre or alternatively would suffice to carry the necessary ewes and fatten 10 lambs of say 340 lb. dressed weight. Average production of butterfat per acre used for dairying in New Zealand is estimated at 120 lb. and average production of lamb 100 lb. The theoretical figures quoted are not unduly high in view of known performance on selected farms. The gap between potential and actual production is a rough measure of the scope for improvement on our better quality grasslands.

Because of the dominance of our livestock industries and their reliance on pasture, our problems relate largely to methods of growing higher-yielding pasture of greater nutritive value and its efficient utilization by improved livestock maintained as free as possible from disease.

AGROSTOLOGY

Pasture Production—New Zealand is a pastoral country ; of the 43 million acres in occupation 31½ million acres are in pasture of various types and only 1¼ million acres are devoted to annual crops. The pasture lands consist of 14 million acres of native tussock grassland, 11 million acres of surface sown grassland established after forest or scrub fires, and 6½ million acres of pastures sown on ploughed land. Each type of grassland has certain major defects ; over large areas of the tussock and surface sown grasslands the problem is one of the development of a close and stable sward to combat erosion and to maintain stock carrying capacity ; in the ploughed grassland the problem is the development of improved fattening and milk producing qualities and a more even seasonal spread of production.

The native tussock grasslands evolved in the absence of grazing animals and, with the exception of blue grass (*Agropyron scabrum*), none of the tussocks is palatable to sheep ; but the grazier soon found that the first growth following the burning of the tussocks was readily eaten by sheep and this led to the regular burning of the tussock grasslands. Indiscriminate burning, overstocking and the destruction caused by rabbits have led to serious deterioration and in places to actual depletion of all vegetation and consequent erosion problems. Besides the native tussocks these grasslands contain numerous other indigenous and introduced plants and it is to such introduced plants as Yorkshire fog, catsear and sorrel that our tussock grasslands owe much of their carrying capacity. The improvement and regeneration of the native tussock grasslands is one of New Zealand's major problems—partly an economic one, for fencing and spelling are necessary for rejuvenation of the native tussocks and introduced plants, *but requiring also the collection from other countries of plants suitable for mountain soil and grazing conditions.*

From the time of sowing to the present most surface sown hill pastures have deteriorated. Originally sown in rye-grass, cocksfoot and clovers, large areas have changed, to danthonia and agrostis, while other areas have deteriorated to fern, scrub and other second growth, particularly on the wet elevated areas of the west coast of the North Island. Pasture deterioration has been accompanied by sheet and slip erosion. Although certain improvement in the sward can be effected by top-dressing and the introduction of white clover in the wetter districts, subterranean clover in the drier, and Lotus Sp. in the warmer areas, these legumes cannot be used successfully over large areas where top-dressing with phosphatic fertilizers is uneconomic. *Lower fertility demanding legumes and edible shrubs should be sought for to improve large areas of marginal surface sown hill country grazing land.*

The productivity of pastures on ploughed land has been greatly increased during recent years by the introduction of improved strains of grasses and clovers, particularly perennial rye and white clover. However, the nutritive qualities in pastures require improvement at certain periods of seasonal growth, particularly in autumn and early spring, when specific diseases in cattle and sheep are commonly associated with periods of rapid pasture growth. *Intensive research into the metabolism of the growing leaf and its relation to stock diseases associated with rapid pasture growth is required.*

Further improvement in production from pastures on ploughed land will depend very largely on increasing growth during the winter months. *Intensification of plant breeding and selective work to develop better winter producing strains of grasses and associated clovers are required.* (P. W. S.)

PASTURE MANAGEMENT

Pasture top-dressing with phosphates and lime is a very important pasture management practice in the Dominion. The area annually top-dressed rose to over $4\frac{1}{2}$ million acres in 1941 and when phosphates are again freely available will probably amount to 5 million acres. Prior to war rationing the annual dressing varied from 2–3 cwt. of superphosphate per acre (or its equivalent in other phosphates) on intensively managed grassland to $1–1\frac{1}{4}$ cwt. superphosphate on less intensively farmed land. *Intensification of research is required into the fixation of phosphates in the soil and the development of concentrated phosphatic fertilizers suitable for hill country use.* The possibility of economically top-dressing hill country from the air should also be explored. A review of world and British Commonwealth resources and annual consumption of phosphates, and a general intensification of research to develop the most economical utilization of available resources appear to be warranted. Nitrogenous fertilizers are little used in New Zealand for the improvement of the winter and early spring growth of grass and *further research is required into the use of such fertilizers and the development of types better suited for grassland top-dressing.*

For the improvement of the milk producing and fattening qualities of pastures more research is required on the development of grazing techniques which will enable fodder to be consumed at the optimum stage of growth, and to extend the period of grazing. Common difficulties in securing optimum growth in weaned lambs and calves appear to be associated

with methods of grazing and *intensification of research into the nutritive value of various types of pastures at varying grazing heights and related periods of spelling is required.*

In the higher rainfall districts supplementary feed for livestock during periods of low pasture growth is provided chiefly by pasture hay and silage and growing or dry standing herbage (similar to rouen or saved aftermath). *Research is required into the management methods and species suitable for carrying a standing grass growth from periods of good production into periods of low production so that maximum feeding value is retained and serious deterioration of pasture sward and subsequent decline in production are avoided.*

Some of the difficulties in securing the optimum value (although not associated with deficiency diseases) from certain grazing lands may be due to deficiency in minor elements. The rôle of molybdenum in the fertility of certain North Island lateritic ('ironstone') soils is now being investigated, and the intensification of research is required on the role of minor elements in soil fertility. (P. W. S.)

FODDER CONSERVATION

In relying wholly on pasture growth as the basis of pastoral industry, the farmer in temperate latitudes is faced with the difficult task of equating pasture growth to stock needs. Top-dressing of pastures with phosphates (and potentially with nitrogen), the use of improved pasture species with better seasonal spread of production, rotational grazing, the saving of autumn growth for consumption in late winter and early spring and other measures all help to extend the period during which stock needs can be fully met by pasture growth. But while the rate of pasture growth remains subject to the vagaries of rainfall, temperature and other seasonal fluctuations there remain periods of surplus and deficiency in pasture production. New Zealand farmers have adapted their farming systems to the seasonal rhythm of pasture growth by late winter and early spring calving of dairy cows so that the peak of lactation coincides with the spring flush of pasture growth and by lambing in early spring so that fattening may be largely completed on pasture.

In a 'normal' season, however, approximately 50 per cent of pasture production occurs in the period October–December, while only 30 per cent of the annual requirements of a dairy herd fall in the same period, i.e., 40 per cent of grass production in this period is surplus to herd requirements in a normal season.

Having reduced seasonal fluctuations in pasture growth as far as prevailing economic conditions permit, and adjusted stock needs as closely as possible to anticipated pasture production, efficient utilization depends on :—

(*a*) fully utilizing pasture as it grows and meeting deficits in growth by :—

(i) use of purchased feeding stuffs,

(ii) the use of crops to supplement pasture at periods of low growth rate, or

(*b*) the conservation of the spring surplus of pasture growth as hay, silage, or dried grass, or

(*c*) some combination of the above methods.

The use of purchased concentrates in New Zealand is negligible except in the case of dairy farms supplying winter milk for town supply, while in the main dairy areas of the North Island only some 4 acres of supplementary crops are grown per 100 cows. In these areas reliance is placed on conservation of hay and silage as the basis of winter feeding, some 30 acres per 100 cows being saved—equivalent to approximately 14 per cent of the area used for dairying.

In the drier and colder areas of the South Island, much greater use is made of crops for autumn fattening of lambs and to supplement winter pasture which under these conditions has a longer period of winter dormancy than in the North Island.

Investigations into the losses of feeding value in ensiling indicate that these are high. Such losses may be subdivided into :—

(*a*) visible wastage due to access of air to sides and top of stacks or silos. Wastage in stacks averages approximately 25 per cent but in properly filled silos should be negligible.

(*b*) invisible losses in dry matter (determined by weighing and sampling all green material entering at filling, and weighing-out and sampling silage as emptied). These losses are very substantial, and may average nearly 50 per cent in well made 50 ton stacks.

The addition of acid (A.I.V. process) substantially reduces dry matter losses but the cost makes it uneconomic under New Zealand conditions, while the addition of molasses or whey does not appreciably reduce losses under experimental conditions.

Losses in hay-making have not been accurately measured but preliminary figures suggest that they may be of approximately the same order as in ensiling.

Appreciation of the magnitude of the losses involved in haying or ensiling is leading to a review of the role of supplementary crops in grasslands farming, and investigation of the losses in 'rouen' or dried roughage left on pastures is also required. Since 60 per cent of the seasonal variance in dairy production appears to be related to the level of prelactation (winter) feeding, and a number of sheep and cattle ailments such as pregnancy toxaemia in ewes and ketosis in dairy cows appear to be associated with rapid mobilization of body fat reserves in periods of low pasture production, the economic provision of supplements to pasture growth is a problem of considerable importance and must be greater in other Empire countries where the seasonal variability of rainfall is often greater than it is in New Zealand. (W. M. H.)

LIVESTOCK BREEDING PROBLEMS

Livestock form the basis of New Zealand farming, and average productivity per unit of live-stock is therefore of prime importance in New Zealand's farm economy.

In the dairy industry production of butterfat per cow provides a convenient measure of progress. Average production per cow has increased by approximately 30 per cent in the period 1920–45, approximately 43 per cent of this improvement being ascribed to conscious breeding and selection (including the influence of change in breed composition of dairy

herds) the remaining 57 per cent being due to improvements in the plane of nutrition of stock (including increase in average length of lactation) and other undefined factors.

The rate of improvement has, however, progressively diminished and sire survey results for 2,386 bulls indicate that their average progeny are barely maintaining the production level of their dams. In other words, no improvement in inherent producing capacity can be achieved *on an industry basis* by the use of the pedigree herd sires at present available.

This unsatisfactory position has developed due to unwarranted emphasis on pedigree *per se* and systems of judgment based on phenotype rather than proven ability to transmit desirable characteristics. Rapid expansion in dairy cow numbers and emphasis on the value of pedigree sires provided an expanding demand and left little incentive for vigorous culling and selection of pedigree stock. Only 20 per cent of pedigree cows are annually under test and many breeders still test only selected animals for Certificate of Record, 90 per cent of such animals being tested only once. The problem is largely one of education, the encouragement of lifetime production records for all pedigree females and the fostering of adoption by Dairy Breed Societies of scientific bases for selective registration, sire evaluation, etc. Progress is likely to be slow but the pressure of informed opinion is already tending to bring about desirable reforms.

More rapid improvement may be achieved by the extensive use of selected proven sires by means of artificial insemination. Further study is required, however, to determine the most suitable means of incorporating such techniques in animal breeding plans to achieve maximum improvement, e.g. should the use of selected proven sires be restricted to pedigree herds thus making the maximum number of sons of proven sires available for natural service in grade herds, or should selected proven sires be used directly on grade herds. The widespread use of such methods must also envisage a considerable expansion of herd-recording to increase the number of proven sires from which animals may be selected for A.I. centres.

In the case of sheep and beef cattle, virtually no attempt has been made to apply modern scientific methods in formulating breeding programmes. Nor has any wholly satisfactory method yet been evolved for evaluating the quality of progeny in sheep where a wide range of factors such as fleece weight and quality, carcass conformation, etc., must all receive due consideration.

The use of progeny testing in sheep breeding, on other than an experimental scale, depends on the development of rapid methods of progeny evaluation.

Detailed studies are also being made of the mode of inheritance of specific defects in livestock, e.g. hereditary photosensitivity in southdowns, parrot-beak in shorthorns, etc.

Raising the average plane of nutrition of stock has in the past proved the most rapid and efficient method of improving unit production of livestock and still remains the most promising avenue for immediate improvement in the vast majority of our herds and flocks. As the average standard of nutrition improves, however (and already in our better fed herds and flocks), increasing attention must be devoted to improving and maintaining a high level of inherited capacity for production. (W. M. H.)

DISEASES OF LIVESTOCK IN NEW ZEALAND

No useful purpose would be served by cataloguing all the diseases of livestock known to be present in New Zealand. This country is singularly free from the disastrous plagues which decimate the domesticated animals in many other countries. With the exception of a few mentioned hereunder, the main problem in connexion with infectious diseases is to ensure their exclusion. On the other hand, metabolic disturbances arising from special environmental effects of pasture are important and in some cases present difficult problems. The following diseases are under investigation:—

Diseases of dairy cattle

Mastitis—As in most countries this is the most serious economic disease of dairy cattle. In New Zealand it presents no very unusual clinical or etiological features. Intra-mammary injections do not appear to have been quite so successful as overseas reports would indicate. In particular, there appears to have been quite serious depression of lactation even when sterilization has been effected. Penicillin has not yet been thoroughly tried. Control by segregation methods and the use of antiseptics will present serious difficulties in New Zealand. Dairying on pasture with the maximum of mechanization has resulted in farm labour being reduced to a minimum, and it would be difficult to introduce procedures into the milking shed that called for any great increase in labour. It is realized that on theoretical grounds vaccines do not offer very great possibilities, and that this appears to be confirmed by overseas experience. Nevertheless the idea is so attractive to New Zealand dairy farmers that they buy some tons of proprietary vaccines annually though there is no evidence that these are of any value.

Contagious abortion—In New Zealand abortion due to *Brucella* is concentrated largely in young cows. For this reason calfhood vaccination with live vaccine made from Strain 19 has been singularly successful, abortions in 2-year-old heifers having been reduced from 20 to 3 per cent. This year approximately 50 per cent of all dairy heifers will be vaccinated. Handling of such large amounts of a live vaccine presents considerable organization difficulties, and the discovery of an effective dead vaccine would be extremely valuable.

Sterility—Male sterility is of considerable importance, and is proving a very real handicap in developing artificial insemination as it is found that bulls which are reasonably satisfactory for hand mating with small numbers of cows under normal dairying conditions, will not stand up to the regime to which they are subjected in artificial insemination schemes. Female sterility is largely of the temporary type, but under New Zealand seasonal dairying conditions when efforts are made to have all cows calve in the spring, it is quite important. Not less than 7 per cent of all diary cows fail to conceive each year. Both male and female sterility are under investigation but no very definite results have been achieved.

Post-calving diseases—Typical milk fever (hypo calcaemia) and typical grass staggers (hypo magnesiaemia) are encountered, but intermediate forms which do not appear to coincide with any recorded conditions are

also seen. These do not respond well to any known form of treatment. Their incidence appears to be higher than normal in years where there is an unusually luxuriant spring growth.

Diseases of sheep

Facial eczema—This is an icterogenic photosensitization which in some years affects cattle as well as sheep. It occurs in the autumn and is only seen in significant numbers of animals when a dry spell long enough and severe enough to suppress the growth of perennial ryegrass is followed by warm autumn rains which induce a luxuriant growth of pasture. The photosensitization has been shown to be due to phylloerythrin, but there is as yet no clue to the nature of the liver toxin. A field station has been established for the study of this disease. Pasture is collected and dried, and that which has been shown by animal grazing experiments to be toxic is submitted to the chemists. Control measures are studied at th out-station, and the main lines of investigation concern the stage of growth of pasture and the use of special crops during the dangerous period. Chemical investigations have revealed the presence of an extremely interesting series of pigmented fluorescent alkaloids in perennial ryegrass, but these do not appear *per se* to be associated with the disease.

Inherited photosensitization of southdowns—In this disease a liver dysfunction appears to be inherited as a simple recessive. Homozygous lambs exhibit a phylloerythrin photosensitization as soon as they graze green pasture; as there is no recovery, the condition amounts to a lethal factor.

Other forms of photosensitization—Photosensitization is occasionally noticed in lambs grazing on rape. The photo-dynamic agent has not been discovered. Icterogenic photosensitization has been reported on *Panicum milliaceum* and on Ngaio (*Myoporum laetum*). Photosensitization from ingestion of *Hypericum perforatum* occurs in some districts and causes considerable inconvenience during shearing and droving through the extreme hyposensitivity to water which is manifested by affected animals.

Hogget unthriftiness—Weaned lambs thrive poorly during autumns in which growth of pasture is very rapid. The relative etiological roles of gastrointestinal parasites and metabolic disturbances have not been fully determined.

Entero-toxaemia—Entero-toxaemia is largely a disease of young lambs in New Zealand. Fair control is achieved from vaccinating ewes with alum precipitated toxoid.

Cl. Chauvoei septicaemia—The black leg organism causes considerable mortality in sheep which have been exposed to various forms of trauma. Serious mortalities have been experienced following lambing, marking, shearing and dipping. Good control is obtained by vaccination.

Enzootic icterus—This presents the usual picture of a high concentration of copper in the liver and haemolytic anaemia. No method of effective control has been devised.

Pregnancy toxaemia—After hard winters serious losses are experienced in pregnant ewes. Control is not always easy as under New Zealand conditions sheep do not take very kindly to fodder supplements.

Prolapse vagina—In some seasons this occurs to a serious extent. It has

not been investigated thoroughly. It is possible that genetic investigations might be the most fruitful line of approach.

Ryegrass staggers—This condition is an ataxia which affects cattle and horses as well as sheep, generally in the late summer or early autumn. It makes it impossible to drive the animals any distance, but usually clears up spontaneously with a change of feed. Though apparently of toxic origin nothing is known of the agent responsible.

Rickets of lambs in Canterbury—During some winters in the Canterbury district weaned lambs grazing on green oats become affected with true histological rickets. This does not appear to be associated with any mineral deficiency nor can it be prevented by feeding calcium phosphate. It can be prevented by a single massive dose of calciferol.

'*Bowie*'—This disease occurs in young lambs in parts of the Marlborough district. It is characterized by a distortion of the front limbs, which are very badly bowed. Recent experiments have suggested that it can be prevented by feeding a composite mineral supplement to the pregnant ewes. There is as yet no indication of the particular element concerned.

Dental erosion—This is of considerable importance in some districts; cause obscure. Both heredity and environment may be involved.

Diseases of pigs

The only disease of any great economic importance is a pneumonia of young pigs. This is frequently associated with a Salmonella, but there are no experimental data indicating to what extent this organism is responsible for the condition.

Poultry diseases

A fatal myocarditis occurs in some districts. Its etiology is quite obscure. The disease known as 'pullet disease' also occurs in New Zealand, but no advance has been made in elucidating its etiology.

Deficiency diseases

Cobalt—There are fairly extensive cobalt deficient areas in New Zealand. The deficiency is effectively remedied by annual pasture top-dressing with 5 oz. cobalt sulphate per acre. In districts where top-dressing is not practised licks are reasonably effective. No knowledge has been obtained concerning the functioning of cobalt in animal metabolism. Australian work indicating that liver is effective in curing the effect of cobalt deficiency has been confirmed and this should give a good lead as the potency of liver cannot be related to its cobalt content.

Copper—Large areas of peat are deficient in copper. This causes pronounced diarrhoea in cattle and ataxia in lambs. The deficiency can be corrected by top-dressing with 5 lb. of copper sulphate per acre annually. There are some indications that other mineral imbalances occur in some peat areas.

Iodine—Iodine deficient areas have been located by conducting iodine surveys of the thyroids of lambs. Goitre in lambs sometimes associated with serious mortality during the first few weeks of life occurs in a very

erratic way, and it is not easy to correlate its incidence with a straight iodine deficiency. (F. J. F.)

GENERAL

Considerable areas of sown pasture land are subject to invasion by weeds such as ragwort, gorse, blackberry, thistles, etc., and more efficacious and cheaper weedicides than are at present available would greatly assist in their control. Differential weedicides for the control of annual weeds in crops would also be helpful.

In view of the general dependence on pasture as the basis of our farming industries, production is subject to considerable seasonal fluctuations according to climatic conditions. Long-range forecasts of periods of sub-normal precipitation would assist in minimizing such fluctuations and reasonably accurate forecasts for even a week ahead would greatly facilitate harvesting and haymaking.

Sheet and slip erosion and to a less extent wind erosion are serious problems on much of the marginal hill sheep-lands, but these problems are dealt with separately.

Under the system of farm-separation practised on New Zealand dairy farms supplying butter factories, the skim milk is retained on the farm and used for calf rearing and the fattening of pigs. As used in New Zealand without grain supplements, some 20 lb. of valuable milk proteins are required to produce 1 lb. of protein in pigmeat and it has been calculated that the protein wasted in the skim milk on New Zealand dairy farms is more than twice the total protein contained in all the cheese and frozen lamb exported from New Zealand. The problem of its more efficient utilization for human nutrition is, however, almost entirely economic.

Breeding and selection work on field crops is proceeding in order to provide varieties better adapted to local conditions, more resistant to disease, etc.

Similarly, problems of varieties, rootstocks, fungous diseases, etc., of fruit trees and small fruit, are receiving attention and considerable progress has been made in the biological assay of plant therapeutics, biological control of insect pests, and so on.

A SURVEY OF SOME OUTSTANDING PROBLEMS IN AGRICULTURAL SCIENCE IN INDIA

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SOME IMPORTANT FEATURES OF INDIAN AGRICULTURE

Physical and climatic

The sub-continent of India presents such a wide range of physical and climatic features as is not found in any area of similar size in the world. Dras (Kashmir) records a temperature of −49° F., while in the plains of Upper Sind a temperature approaching 130° F. in the shade has been recorded. While the mean annual range of temperature is only 20° F. in Cochin (South India), in many parts in the north even the daily swing may be often wider than this ; and the normal annual range may be more than three times this figure.

The intensity of sunlight and daily duration of sunshine exhibit strikingly large regional and seasonal variations.

Cherrapunji in the north-east has an average rainfall of 430 inches, and certain parts of the Western Ghats may get 350 inches, the Desert of Rajputana gets less than 5 inches, and parts of Sind as little as 3 inches per annum. While humidity may be 100 per cent at one time of the year, it may be almost 0 per cent, at another time.

The diversity is present in altitude as well. There are coastal regions where cultivated lands have to be walled round to keep out sea-water, and there are heights above the limits of vegetation. Hills of various heights, scattered in several regions, modify climatic conditions and add to this diversity.

Rain-laden cold currents of air and dust-laden hot wind-storms present a striking contrast.

The result is that while extensive areas show most wonderful growth of vegetation during the greater part of the year, several areas are sunburnt, dreary wastes, with not a blade of grass, during some parts of the year.

With such a variety of conditions, it is not surprising, that in one region or another, it is possible to obtain conditions suitable for the cultivation of almost every kind of crop, vegetable, flower and fruit of the temperate, sub-temperate and tropical zones. While this diversity provides for variety, at the same time over extensive areas the environmental conditions are so inhospitable that profitable farming is a matter of great difficulty and uncertainty.

In the diversity of her soil types India competes with other continents. However, four main types may be recognized. Agriculturally the most important are the great alluvial plains, because they are the most extensive

—the Indo-Gangetic Plain extending as a wide belt right from Sind to West Assam—and respond remarkably to manure and irrigation. These soils are, on the whole, easy to cultivate, but have a tendency to develop alkalinity under conditions of high temperature and low rainfall. The black cotton soils lying over the Deccan Trap are characteristic of the greater part of Bombay, Berar, the Western Central Provinces and Hyderabad and extend into Central India. They are the richest of all soils, as they contain vast reserves of nutrient materials. They are difficult to cultivate, require careful watching of their physical condition, which is prone to wide variations. The red soils of Archaean origin are found in Madras, Mysore, south-east Bombay, east Hyderabad and the Central Provinces, and penetrate into Orissa, Chota Nagpur and South Bengal. The Laterite soils encircle the peninsula and extend into Bengal and Assam. Both these types are acidic in character, they are deficient in nutrients and require heavy manuring to maintain them at a reasonable level of fertility. Thus all the various types have problems of their own.

The most dominant factor in the Indian agriculture is the monsoon. Over the greater part of the Indo-Gangetic Plain and the adjacent regions the rainfall occurs between June and September. The rest of the year is mostly dry, except that December to March may get a rainfall of 2 to 5 inches. The *kharif* or summer crops—rice, millets, maize, pulses, cotton, jute and ground-nut—are grown during the monsoon. Sugar-cane, which is on the ground for a year, has its chief period of growth during the rains. The *rabi* or winter crops are wheat, barley, linseed, rape and mustard. In South India the bulk of the rainfall is received from October to February, and the crops grown are rice, millets, cotton and ground-nut.

Of the 280 million acres (approximately) of cultivated area, roughly 220 million acres depends entirely upon rain. And, rain is an exceedingly variable factor. Besides the regional variations mentioned above, the annual variations are equally marked. The average rainfall of the Indo-Gangetic region is 42 inches and variations of +12 and −11 inches from the normal have been recorded. Again there are striking variations in time and space, early and late arrival, long breaks and abrupt finish. The monsoon may fail or there may be heavy downpours, resulting in floods and causing destruction of life and property over extensive areas. A rainfall of 10 to 12 inches a day is not a very rare occurrence, and at Purnea in Bihar 35 inches in 24 hours has been recorded. A perfect monsoon is a very rare phenomenon. It will be evident that any alteration in the programme of the monsoon, or any variation in its extent, intensity or duration, will have direct effect on the area sown as well as the yield of the crops sown. The monsoon determines the prosperity and nutrition of the people of India.

Sociological

A fundamental feature of Indian agriculture is that it has to provide for the needs of a population of 425 millions, which is increasing at a rate exceeding 5 millions a year. Further it has to provide food for a cattle population of over 200 millions, and about 100 million sheep, goats, horses and other animals. For this reason food production is the main feature of Indian farming. The total area under food grains (cereals and

pulses) and edible oil seeds is 244 million acres. To this may be added another 11·5 million acres under other food crops, such as sugar-cane (4 millions), tea, coffee, condiments and spices (3 millions), fruits, vegetables and root crops (4·5 millions). There is roughly 25 million acres under cotton, and as cotton seed is food for cattle and some of it is used for the manufacture of hydrogenized oil for human consumption, one third to one quarter of this area could reasonably be included under food crops. Therefore the balance purely non-food crop area is approximately 10 per cent of the cultivated area. Even then the land available per capita for food production is not more than 0·6 acres. And, this proportion is decreasing with increase of population. When considered in conjunction with the general low yield of crops in India, the conclusion is inevitable that the nutritional standard of the people is very low. It has been estimated that the percentage increase in the production of various foods required to provide a suitably balanced diet in minimum quantity for a population of 400 million people is :—

cereals by 10 per cent,
pulses by 20 per cent,
fats and oils by 250 per cent,
fruits by 50 per cent,
vegetables by 100 per cent,
milk by 300 per cent,
fish and eggs by 300 per cent.

The position to-day, when the population is very near 425 million, has deteriorated further.

While food grains are consumed by the human population, straw and stock of these crops with grasses form the food of cattle. To these may be added small quantities of oil cakes, bran and pollard as concentrates. The available quantities of roughages and concentrates on a most modest estimate fall short by 22 per cent in the case of roughages and 71 per cent in the case of concentrates. Ill-fed cattle are not capable of giving good service, either as draught cattle or as milch cattle, and, therefore, a large number has to be maintained. The place of cattle in the farm economy of India is a feature of Indian agriculture, which demands immediate attention and careful consideration. The cattle provide labour, milk, flesh, manure and fuel; and raw material for several industries (hides, hair, horns, bones, etc). It has been estimated that the value of cattle to India in terms of money is the same as the value of farm crops.

The most characteristic feature of this farm economy is that cattle dung, which provides most valuable material as manure and humus for the soil, is burnt in very large quantities, because an alternative cheap fuel is not available.

Another feature of Indian agriculture is that it is a land of small farms, 4 to 5 acres may be taken as an average farm, on which a family of four or five has to maintain itself. This type of farming places limitations on the possibilities of improvement, and with any slight mishap to crop or live-stock steeps the farmer in debt. In the absence of any subsidiary remunerative occupation the returns from such farms do not provide for all requirements of the family.

To these specific features may be added the general drawbacks of prevailing illiteracy, devitalizing diseases (such as malaria), lack of industries, subsidiary occupations, and so on.

While previously famines in India were the results of an inadequate system of transport (this was remedied by extension of roads and railways), and of insecurity in food production in certain parts because of the failure of the monsoon (this was counteracted by the development of irrigation systems), the recent Bengal famine (1943) and the present food shortage clearly indicate that the country as a whole has ceased to produce all the food that is required for her population. The efforts of the ' grow more food ' campaigns, stimulus of very high prices for food crops, propaganda and State subsidies have not been able to solve the problem. These are sure signs of a difficult position. Without imports, which have been progressively increasing during recent years, it is not possible to provide for the nutrition of the people, even at a very low level. Population has outstripped food production, low standards of life and deterioration in physique are evident. The problem has become most complicated. Variety of conditions, in different parts of the country, demand a regional study of the problems. But in each region the problem must be studied as a whole. The improvement of Indian agriculture is as much a sociological problem as it is technical, and the two cannot be separated. Piecemeal treatment will only increase difficulties. A co-ordinated development of all aspects of social life alone can provide an answer. Education, public health, control of cattle diseases, crop husbandry, animal husbandry, marketing, co-operation, industry, etc., all impinge on each other at every stage. Isolated measures consequently bring no relief. Radical change in the entire life economy of the farmer is essential, and this needs a careful planning and a bold constructive programme.

It is against this background that the problems of agricultural science in India have to be surveyed.

SOME IMPORTANT PROBLEMS OF AGRICULTURAL SCIENCE IN INDIA

The outstanding problem of agricultural science in India is to make adequate quantity of suitable food available for the growing population of the country. This problem can be solved : (*a*) by the extension of the area under cultivation, (*b*) by extending irrigation facilities wheresoever and howsoever possible, (*c*) by improving dry-farming methods where irrigation is not possible, (*d*) by increasing the yield of crops per acre, (i) by raising the fertility of the soil by natural methods and by manures and fertilizers, (ii) by growing improved varieties of crops, vegetables and fruits, (iii) by extending the cultivation of crops which give higher yields of food per acre, (iv) by increasing the yield of crops and reducing wastage by the control of pests and diseases, (*e*) by improving livestock and increasing the yield of milk, flesh and eggs, (*f*) by introducing mechanization and thereby reducing the number of bullocks and thus making provision for the better feeding of milch cattle and increasing the supply of milk, and (*g*) by careful processing of food and its preservation to make the most of what if produced.

Although food production is by far the more important aspect of Indian farming, India produces large quantities of cotton for her own requirements and much of it was exported before the war. A great deal of improvement has been made in producing cottons with long staple and higher yields. India has the monopoly of jute production. Various other fibres are also produced. India produces castor oil, linseed oil and several agricultural products for industry. The problems of their improvement are in the main the same as those for the food crops.

Problems of irrigation

While the rainfall is the only source of water supply for 220 million acres of cultivated land, it is supplemented by artificial irrigation over an area of 60 million acres. One half of this irrigated area, that is 30 million acres is served by canals ; 15 million acres is irrigated by wells ; and the remaining 15 million acres by reservoirs, tanks, streams, etc. In tracts with an annual rainfall of below 12 inches, no crops can be grown without irrigation. This is true of many parts of west Punjab and Sind. There is a vast tract of a million square miles, mainly in the south-east Punjab, and the United Provinces where irrigation must supplement rainfall to make it secure from uncertain rainfalls. In this tract irrigation permits of extension of acreage of *kharif* crops, and doubles the yields of *rabi* crops. Here sugar-cane cultivation is only possible because of irrigation.

Further extension of the area under cultivation is possible mainly through the extension of canal irrigation. In the post-war plans are included various schemes of irrigation, and it is proposed to construct several big dams. Many of these schemes will be multipurpose, and will provide for the generation of hydro-electric energy, for canal irrigation and for fish propagation. The power generated will be utilized for industrial purposes, as well as for agricultural purposes, such as lifting water for irrigation from the sub-soil. Rapid execution of such schemes and their proper working will greatly help in agricultural prosperity. India needs machines for the early execution of this task.

Canal irrigation, while it provides the cheapest form of irrigation, and enables crops and fruits to be produced from almost desert areas, in many parts of India it has created serious problems. This irrigation has led to water-logging and salt formation. In the Punjab alone it is estimated that 2 million acres of good land have gone out of cultivation, and about 0·5 million acres is going out of cultivation every year. In this Province the total canal irrigated area is 13 million acres. This is a serious problem of which a satisfactory solution has yet to be found. Cheap electric power may be the solution, as water could be pumped out of the water-logged soil, and salts could be washed down from saline lands by applying abundant water to them.

Well irrigation is of very great importance in various parts of the country, and in certain tracts this is the only source of irrigation. There are several schemes in different provinces for extending well irrigation through financial help from the State. There are two types of wells, surface percolation wells and tube wells. Many of the percolation wells are small, yielding less than 1,000 gallons per hour, and demand 50 to 60 hours' work to give light irrigation to one acre. These require bullock power for lifting water,

either by means of Persian wheel or *charsa* (a large leather bucket). Various improvements in these water lifts have been made. In several parts of the country tube wells are being sunk. These wells tap water resources from deeper strata, and the water is lifted to the surface by pumps, worked by oil engines or electric motors. The problems here are of three types :

(*a*) determination of the volume of underground supply,
(*b*) lifting the available supply to the surface cheaply,
(*c*) the quality of the water available.

If the quantity available is not ample the well or tube well may fail, the depth from which the water can be profitably lifted depends on the cheap supply of power, and if the water is saline the entire cost of sinking a well is lost. A complete and careful survey of underground water resources is a great necessity. Any methods by which this can be done quickly and cheaply will be a boon to many parts of India.

Storage reservoirs, artificial lakes or tanks in which rain water could be stored for use during the dry period are an ancient system of irrigation. This system serves for 15 million acres and can be extended. Many of these storage tanks could be used for irrigation and propagation of fish. As stated above, the success of these subsidiary means of irrigation depends almost entirely on cheap power to lift water. If this power is available, water could be lifted from lakes, streams and rivers for irrigation, and land brought under cultivation for valuable crops, vegetables and fruits in some hilly localities.

An outstanding problem in irrigation is the judicious use of water for raising different crops. Accurate scientific knowledge is lacking, and there is wastage through lack of co-ordination of cultural treatment and water requirements of crops. Little attention has been paid to this problem.

Problems of dry farming

Even after a full development of all irrigation resources there will be vast tracts in India where rainfall will be insufficient and badly distributed and possibilities of irrigation non-existent. In such tracts dry farming will be the only possibility. The problems of dry farming are numerous and most intricate, depending upon the locality under investigation. Some of the problems are being investigated with useful results. It is not only conservation of moisture which is of importance but suitable rotations have to be evolved, suitable farm practices discovered and suitable types of crops grown.

Problems of soil fertility

Second to an assured supply of water, manuring is the most important factor of rapid increase in crop production. The problem of manure supply, however, is one of the most difficult problems of Indian farming, and no satisfactory solution of it has been found so far. For an Indian farmer the farmyard manure is the most important, as it is cheap and is

readily available, and further it adds both humus and nitrogen to the soil. At present it is estimated that not more than 40 per cent of cattle dung is used as manure, an equal quantity is burnt as fuel for household cooking, and the remaining quantity is lost as it is not collected. As long as a cheap fuel is not readily available in villages it is not possible to stop the use of dung cakes as fuel. It will not be wrong to say that the solution of the problem of soil fertility lies in the fuel. Remnants of certain crops such as cotton sticks are used as fuel. Forest plantations near villages, quick growing hedges around fields as wind breaks have been suggested to increase the supply of fuel. Nothing effective has, however, resulted. Development of cheap electric energy, or use of other forms of energy—such as the atomic energy—for objects for which coal and mineral oils are used at present, may release these fuels for household purposes. In due course even cheap electric energy may be utilized for certain household needs in an Indian village, but that will take time. For the present, therefore, the problem is to improve the efficiency of the village hearth, and provide in the scheme of crop rotation a fuel alternative to cattle dung.

It is estimated that even if the whole of farmyard manure is used for manuring land, it will only supply about 30 per cent of the total requirement of nitrogen. We have yet to obtain precise information about the quantity of nitrogen fixed by soil organisms, in different soils, under different types of cultivation, and the maximum which these organisms could fix under optimum conditions. The fact that even soils which have not been manured continue to produce some crops, year after year, indicates that the quantity of nitrogen, obtainable through the natural recuperative powers of the soil, must be considerable. The problems involved are some of the most fundamental. These problems have to be studied under most diverse physical and climatic conditions, and for diverse types of soils and systems of cultivation.

Besides farmyard manure, compost from night soil and street sweepings of towns, and from cattle manure and vegetation in villages, and green manuring supply humus and nitrogen to the soil. Efforts are being made to encourage these, but it is too early to say what results will be achieved. Other forms of manure such as oil cakes from non-edible oil seeds (neem cake and castor seed cake), bone meal, fish manure are available in small quantities, and before the war were chiefly exported. Oil cakes from edible oil seeds are needed for cattle. It is necessary that all oil seeds are crushed within the country and all export of manure stopped.

Before the war India used very small quantities of chemical fertilizers. The total quantity of ammonium sulphate used was 120,000 tons a year (of this 20,000 tons was manufactured in the country). A greater part of this small quantity was used for special crops. It has been decided to establish factories for the manufacture of ammonium sulphate and to encourage its use for such crops as rice. It is generally stated that it will pay a farmer to use ammonium sulphate if the price per maund equals the price of a maund of paddy. If the price of the fertilizer is in excess of this then it would not be an economic proposition. To obtain best results from any fertilizer it is necessary to make a careful study of its potentialities, the period in the growth of the crop when it can give best results and its effects on the soil. These problems have to be studied.

Problems of better varieties of crops

A great deal of most useful work has been done by economic botanists in India, in introducing and acclimatizing foreign varieties of important crops, and in evolving through 'pure line selections' and hybridization more valuable strains, giving better returns and superior products. Indigenous and exotic materials have been used for this purpose. We have to-day improved varieties of sugar-canes, long-staple cottons, wheat, rice, certain millets and oil seeds. In case of cash crops such as sugar-cane, cotton, jute, improved types have been taken up by the cultivator very quickly. To-day 68 per cent of the area under sugar-cane is of the improved Coimbatore varieties, and superior varieties of cottons are grown over 27·5 per cent of the area under this crop. Half the area under jute is grown with improved types. However, the same success has not been achieved in the case of cereals. Improved varieties of rice, the most important of the cereal crops, are grown over 4·5 million acres, constituting only 6·2 per cent of the total area under this crop. Improved types of millets do not cover more than 1·1 per cent of the area under them. The best results have been attained with wheat, in which case superior types are grown over 7·9 million acres, comprising 22·4 per cent of the total area under this crop.

The reasons for this are worth investigating. Taking the case of wheat. During the last 40 years several high yielding strains have been evolved, and for the last several years more than 20 per cent of the area under wheat must have been under these types. Again during the last 40 years the area under wheat has increased by 40 per cent, mostly on land brought under plough through irrigation. The available statistics, however, indicate that the yield per acre has declined. This phenomenon may be the result of defective statistics. It may be, equally probably, the result of unsuitable lands being put under wheat crops. Or, it may be that the Indian soil is not able to provide adequate food for the better types to exhibit their best performance. This raises two important questions. For superior variety, superior condition of water and manure must be made available. Or, the plant breeder must take into consideration all the numerous environmental factors, in which the new types have to function. In addition to the yield factors or quality consideration, the varieties produced must be resistant to disease, pest, drought and storms, cold and heat, etc. In other words, plants with a wide range of biological potential or a wide range of adaptability must be selected in preference to plants excelling in one particular direction.

It is evident that for the development of efficient types, such initial hereditary material must be available as contains a very wide range of characters. Having recognized this, it becomes necessary to explore centres of origin of cultivated plants and make collections of initial plant material from which domesticated varieties have arisen. The potato crop illustrates this point remarkably well. This crop had been grown in Europe for 350 years. Numbers of varieties were produced during this time. The genes present in these varieties were utilized and all desirable combination of them had been obtained. Ultimately a position of stalemate had been reached and no improvement seemed possible, although several problems

such as those of late blight and virus disease remained unsolved. The necessity of introducing disease resistant genes was felt and a search for these in the original home of the potato was made. Expeditions were sent by the Russians to Central America and Mexico in about 1926 and the Empire Potato Collecting Expedition made a wide collection of the species and varieties of potatoes which are now being studied at Cambridge with the financial assistance of the members of the Commonwealth. It is expected that the work undertaken will provide vast numbers of varieties suitable in different parts of the world.

It is by such exploration, through common efforts of the scientists of different countries that improvement of existing crops can be made and new crops for domestication can be discovered.

The task of varietal improvement is tremendous, and as has been said above, the characters to be considered are numerous. Problems of such magnitude can only be solved satisfactorily and quickly by chains of plant breeding stations situated in different localities and carrying on co-ordinated schemes of work. Free exchange of information and material among the investigators will prove a boon to all.

In the past every part of the globe has benefited by the introduction of varieties from other parts. For instance, India has received long staple cottons and many varieties of fruits and vegetables from other countries. Many of the chief crops in America have been imported from elsewhere. In future also importation of suitable varieties of crops will be one of the means of improving agricultural crops. Perhaps one of the great needs of India is the introduction of suitable fodder pasture grasses from elsewhere.

There is one other problem that is important. There are certain plants, for instance sugar-cane, of which certain varieties do not flower ordinarily in tracts where they are grown. Although it has been possible to make some of the varieties flower by changing their environmental factors, yet there are others which have not yielded to such treatment. It may be possible to discover centres where a particular crop is not grown but where conditions would be such that it would produce flowers and enable experiments to be conducted in crossing such plants for the benefit of another country.

Further it may be possible to arrange chains of centres and obtain two or three generations of a certain variety in a year and thus accelerate the speed of experimentation. It has been possible to have a crop of wheat during the winter in the plains of the Punjab and during the summer at an altitude of 10,000 ft or so in the Himalayas and thus have two generations of a particular strain during the course of a year.

Mutual facilities of this type will greatly help to solve the problems of improving varieties.

Problems of fruit and vegetable improvement

India provides in abundance soil and climatic conditions for fruits and vegetables of every region of the globe. There are numerous indigenous varieties of fruits and several important varieties of fruits have been introduced from different parts of the world. New varieties are appearing constantly and there is always scope for fresh introductions and trial. Evolution of new varieties of fruits is a laborious process and takes a long

time. It is, therefore, a matter of considerable importance if exchange of new varieties, useful stocks, disease and pest resistant types is arranged. It may even be possible to adopt available means of quick transport for the distribution of budwood for rapid introduction of tried varieties in a new locality. Collection of varieties of different fruits in suitable centres will make experimentation easier than is the case at present. What applies to farm crops applies to fruit and vegetables equally. It may be possible to evolve varieties that will suit a particular country in a centre outside that country.

India has been importing large quantities of seed of exotic types of vegetables, and even when these vegetables can be grown in various parts, many of them do not seed in this country. During the war successful attempts were made to multiply seed of such vegetables in some selected localities. If vegetable growing is to become popular in India, then the supply of cheap and reliable seed has to be ensured. Proper scientific work on vegetable improvement has only been started on a comparatively small scale recently in India and a great deal has to be done. India shall have to depend on foreign seed and new varieties of vegetables for many years.

Some neglected crops with great potentialities

The nutritional problem of India has become so acute, that there is need for a most rational utilization of land resources, with a view to obtaining the maximum food per acre, always keeping prominently in view the requirements of a balanced diet. The present food economy of India is based on cereals. Will cereals solve our difficulties? Would not a partial switch over to tubers or other highly yielding crops be more advantageous? This is a fundamental problem. Ireland, England, Germany and many other overpopulated countries of Europe, have resorted to potatoes to solve their food problem. In India the potato is a recent introduction, and the area under this tuber has just reached 0·5 million acres. It is only recently that a scientific study of this crop has been undertaken and arrangements for the multiplication of disease free seed made. The more familiar tuber crops of India are sweet potato and cassava. These have had no place either in the statistical return or among the crops under investigation by the Departments of Agriculture. There are hardly any crops that come anywhere near them in the yield of calories per acre. Nothing has been done to produce better types, evolve improved methods of cultivation or encourage their production by methods of processing, such as dehydration to reduce bulk for transport purposes or storage. In the U.S.A. and certain parts of the Commonwealth the sweet potato has received considerable attention. Introduction of varieties of sweet potato, or other tuber and root crops, for trial in India is desirable.

Another crop of promise on which thorough investigation is needed, both from the point of view of agronomy and food technology is soyabean. Nutritional experts in India have given their verdict against it. Should the question be reopened?

Problems of food technology

The food position of India is such that whatever food material is available, must be fully utilized, and made the best use of. Processing should be such

that the maximum benefit is obtained from the supply in hand. What is abundant at a particular season should be preserved in a suitable manner for use during a season of scarcity. What is not very palatable should be made palatable. It was noticed that during the last famine in Bengal, the people used to rice found it difficult to switch over to wheat or millets. Food habits of people get specialized, and while it may be difficult to change food habits, it is quite possible to convert any type of food into a material which fits in with the food habits of a people. Production of yeast from waste product is one method of solving the problem of protein deficiency. Dehydration is a method of particular value for Indian conditions. It should not be difficult to reinforce starch from cassava with proteins and vitamins and thus convert it into a perfect food and give it the shape and taste of rice. There are numerous problems in food technology which await solution.

India is grossly short of fats and oils for man, concentrates for cattle and oil cake for manure. It is, therefore, most essential that the oil crushing industry be extended and improved, and edible oil seed meal suitably processed for human and cattle food.

Pests and diseases

The collections of insects and fungi made in India were sent to specialists outside the country for identification, with the result that type specimens were retained by those specialists, and are now scattered all over Europe. It is most essential that we have in India a complete named collection of insects and fungi for reference. The Imperial Bureaux may help India in this object.

India has not had a proper plant protection service so far, and, therefore, has received several serious pests and diseases from other countries. Mention may be made of San Josê scale, woolly aphis, potato tuber moth, and virus diseases of potatoes. Spread of pests and diseases is a matter which concerns all countries and is a problem which needs international control. India has now started a proper plant protection service. Co-operation is sought to make plant protection effective.

Another problem of very great importance to India is the biological control of pests and weeds. Introduction of *Aphelinus mali* to control the wooly aphis, and of *Rodolia cardinalis* to control the fluted scale (*Iceriya purchasi*) have been very successful. Similar success has been achieved by *Dactylopius tomentosus* against prickly pear (*Opuntia dillenii*). Discovery of similar means of dealing with *Lantana aculeata*, *Eichomia craniper* (water hyacinth), *Saccharum spontaneum* (*Kans*) will be a boon to India. If no natural enemies exist to-day which would be effective in dealing with these pests, is it not possible to force some insects of closely related plants to change their food habits and thus train them to deal with these weeds which have baffled us so far ?

A large number of diseases affecting cereal crops have been investigated, and some are under investigation. Many of the diseases of oil seed and forage crops, vegetables and fruit trees, still remain to be investigated. Among the fungal diseases of cereals, Helminthosporium disease of rice, and *Sclerospora garminicola* of *bajra* are of particular importance. Similarly loose smut (*Ustilago tritici*) occurs widely in India.

Virus diseases are under study, and this is a problem which effects all countries.

Deficiency diseases and diseases due to adverse environmental factors need very careful and prolonged investigations.

Pests and diseases that damage grains, fruits and other products are of great importance to India. These are common to all parts of the globe and deserve to be studied and controlled through common efforts.

Evolution of varieties of crops and fruit trees which are resistant to specific pests and diseases is of great importance to India. In this field of work international co-operation will be most welcome. Resistant materials could be tried at various centres. India needs for instance rust resistant wheats, virus resistant potatoes, jassid resistant cottons.

An international organization to deal with locusts has paved the way for similar studies of and campaigns against other pests which threaten large areas of land extending over different countries. It may be possible to study several other pests and diseases by chains of stations and control them by international action.

The use of insecticides and fungicides is very limited in India, the main reason being the cost of chemicals and machinery for applying them. There is need for the manufacture of insecticides and fungicides and spraying and dusting machinery in the country.

Problems of Animal Husbandry

In most parts of the world, cattle are valued chiefly for their milk and meat. On the other hand, the importance of cattle to India is based on different criteria. A vast proportion of the population is vegetarian, and of the rest some eat fish, but not flesh, and of those who eat flesh a very large section does not eat beef, and an equally large section does not eat pork. In apportioning value of cattle to India, it is estimated that cattle labour accounts for 45 per cent, manure (including fuel) for 20 per cent, milk for 30 per cent, and flesh, hides, etc., contribute the balance. In fact cows are maintained primarily for producing bullocks for draught purposes, and for obtaining manure (as also fuel). Efforts have been made to improve the draught qualities of cattle but the chief aim has been to produce a dual purpose breed—suitable bullocks and good milch cows. It has been shown that through proper management and feeding and selective breeding, high quality milch cows of a pure Indian breed can be produced, without impairing the draught quality of the male. In India to-day there are pedigree herds of cows which give an overall yield of 20 lb. of milk per head per day, containing 5 per cent of fat. The high yield of milk and more particularly high fat percentage have attracted the attention of dairymen in many countries and demands for pedigree bulls are being received from such parts of the world where climatic conditions resemble those of India.

In cross-breeding the emphasis was always on milk production. Various crosses between bulls of some European breeds and Indian cows were attempted. While F_1 generation milch cows were very good milkers, the subsequent generations showed rapid deterioration both in the males and females. Cross-breeding has not been successful as a measure of permanent breed improvement. This method, however, has a place in any scheme

of immediate increase of milk supply, particularly near big cities, where herds of F_1 generation milkers could be maintained. Importing valuable bulls from abroad and exposing them to the rigours of the Indian climate and to disease cannot be recommended. Now that the technique of artificial insemination has advanced and quick air transport has developed, it is worth consideration whether 'sperm banks' established in different centres, will not be useful in large scale experiments in cross-breeding, and rapid increase in F_1 milch cows.

While the cow is maintained by the Indian farmer for her male stock, the buffalo is his real milch animal. Progressive increase in the number of buffaloes points in this direction. So far very little work has been done in improving the breeds of buffaloes. Co-operation with other countries for the improvements of this milch animal, which produces milk with a fat percentage much higher than that in the milk of the cow, will be of great advantage to every country.

India's consumption of milk per head per day is only 7–8 oz., and for proper nutrition this must be more than doubled, as milk is the only source of proteins of high biological value available to a people who are mainly vegetarian in diet. India is, therefore, keenly interested in all experiments which are in progress in increasing milk yields.

In any scheme of cattle improvement, the most fundamental problem is that of food for cattle. India is grossly short of fodders and concentrates for her enormous cattle population. There is keen competition for food between man and cattle, and the solution of this is far from easy. India would welcome the introduction of any grasses, fodders crops or fodder trees, which will help to solve the problem.

To provide milk to her population in adequate quantities, it is not unlikely that India will have to provide for the milk supply of her small farmer from a smaller animal—the goat or even the sheep. India has certain breeds that are good milkers, but she needs better breeds. It will be desirable to combine the milk yield character with characters of good wool, skin, etc.

In poultry—fowls and ducks—India has some good breeds, and of fowls several breeds have been imported and crosses attempted. Development of the poultry industry is a matter of organization and control of poultry diseases.

It was suggested by the military that rabbits be introduced into India from Australia with a view to increasing the meat supply in the country. The Government of India, after obtaining advice, came to the conclusion that it would be dangerous to introduce this animal, as it might become a pest as in Australia. India has several wild carnivores and large birds of prey, and if rabbits are bred under proper control, the few that might escape would not be able to survive and multiply so rapidly as to become a menace. The problem needs a careful re-examination. In many parts of the country wild hares (*Lepus ruficaudatus* and *L. nigricollis*) exist. In some parts of the country domesticated varieties are kept in small numbers. These have not been able to become pests.

At this place the bigger question of the importance of wild life to India may be considered. At present the mention of wild life either brings to mind the picture of tigers, leopards and elephants, or wild pigs and

deer. The latter make cultivation impossible over extensive tracts because of their depradations. There are several birds, such as parrots, crows and sparrows which are a scourge. On the other hand there are several mammals and birds which under proper control and management can provide substantial addition to the food resources of the country. So far even a beginning has not been made to study the wild life of India from this point of view.

Problems of apiculture

While bee-keeping is an ancient industry, in India scientific apiculture is a recent development. There has been a good deal of controversy regarding the introduction of European bees into India, because of the danger of bringing in 'foul brood.' It should be possible to improve the local bees by selection. Perhaps artificial insemination may be helpful in this case as well.

Problems of mechanization

At present the bullock is, almost entirely, the only source of power on the farm, whether for cultivation, water lifting, transport, or working the cane crusher, grain grinding mill or oil mill. The efficiency of cultivation depends upon the capacity of the bullock. While certain tracts produce strong animals, over a greater part of the country, where the density of human and cattle population is high, the bullocks have become weak and small in stature, through generations of ill feeding and careless breeding. The improvement of bullocks depends entirely upon the improvement of food for cattle. In this respect there is keen competition between man and animal, and man naturally comes first. In the existing circumstances there is no likelihood of increasing, appreciably, the area under fodders. The only alternative is to reduce cattle population. Milk supply has to be increased to provide for adequate human nutrition, therefore it is the bullock population that has to be decreased. An attempt to reduce the number of bullocks by evolving more efficient tillage implements or bullock-carts or Persian wheels, is a remedy of very limited application and slow action. Large scale and rapid reduction of bullocks is only possible through mechanization of agriculture. For stationary work electric motor and internal combustion engines must be popularized, and for cultivation and traction, tractors must be used. Introduction of tractors for farm operation has been a very slow process. There may be a few score tractors scattered all over India, owned by big estates or Departments of Agriculture, but this number is far too small even for an experiment. Again, so far, tractors manufactured for British and American conditions have been imported, and no tractors have been designed to meet Indian conditions.

It has to be recognized that mechanization of agriculture to be successful must be introduced on an extensive scale and all at once. A network of depots of spare parts and a chain of repair and service stations are essential features of any scheme of mechanized farming which hopes to achieve success. These depots and service stations can only develop if there are large numbers of tractors in a locality. Further tractors and implements suited to Indian conditions must be designed and produced in the country.

It is often argued that the introduction of mechanization must be preceded by a movement for collective farming, because mechanized cultivation is impossible on holdings of 4 to 5 acres. On the other hand it should be realized that mechanization if introduced in a proper manner would inevitably lead to co-operative farming, and under Indian conditions this would be the proper approach to the solution of this difficult problem. Farmers will not be able to purchase tractors and equipment. To begin with, either the State or the tractor manufacturing concerns shall have to organize tractor cultivation on contract basis. The cultivator when he finds that he can get his work done cheaply, more efficiently, with less drudgery, will be prepared to discard his more costly and less efficient method of cultivation with bullock labour. Disbanded soldiers from a mechanized army are available for such a task on a large scale.

It is emphasized that the main object of mechanization in Europe and America is to save human labour, in India it will be to save bullock labour, and thus reduce the number of work cattle and provide better food for the milch cattle and increase milk production. Mechanization would inevitably lead to the saving of human labour. This labour would be absorbed in tractor manufacturing concerns and repair and service stations, and will be available for improved social services.

PROBLEMS IN AGRICULTURAL SCIENCE IN AUSTRALIA: RUMINANT NUTRITION AND GENERAL AGRICULTURAL EDUCATION

By H. R. MARSTON
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FOR the most part, research in ruminant nutrition has been prompted by problems arising from the immense animal industry which provides civilization with an important part of its food and, at present, with part of its clothing. The disposition of animal production has led investigations into different channels; in the old world attention has been devoted mainly to problems of intensive feeding practice; in the more recently settled areas research has been concerned more especially with nutritional disabilities imposed on grazing animals by climate and terrain.

Many aspects of the physiology of ruminants which must be more completely understood if the main problems of animal industry are to be solved have been seriously neglected. The following note is a plea for greater activity in this field.

Subjects which are not of direct interest to human medicine but of fundamental importance to agriculture have been set aside, and for want of sound bases the teaching of those aspects of animal physiology which directly concern animal industry has assumed a degree of sophistication which tends to confuse rather than provide an inspiration to proceed by research to a more complete understanding of the physiological economy of our farm animals. This lack is not so apparent in kind environments where tradition has stabilized agriculture—other than when a state of emergency demands greater efficiency in the utilization of fodder. It is felt acutely, however, where less favourable grazing conditions call for greater knowledge if industry is to be reasonably effective.

The chemical transformations effected by the rumen flora ultimately responsible for the utilization of cellulose are by no means completely understood; nor are the intermediary metabolic processes which underlie the energy transactions of ruminants. Current feeding standards are based either frankly on empiricism or at best on an incomplete acquaintance with the facts. Our knowledge of the conversion and utilization of protein by ruminants is fragmentary and our appreciation of the quantities of accessory food factors and inorganic adjuvants necessary for normal function of the animal itself and of the symbiotic flora which inhabit its paunch is such as to have been at times seriously misleading.

In the past Australian animal industry has suffered from the bogus catchwords 'iodine deficiency' and 'aphosphorosis.' The former was easily enough scotched; there was a fund of knowledge in the field of human physiology to draw upon. The latter, however, threatened to

become chronic ; it took several years to demonstrate that tacit assumptions, even of visiting experts, are not a reliable guide, and meanwhile commercial interests ever ready to provide for the wants, imaginary and real, of a rich pastoral industry had expanded the annual sales of worthless ' mineral licks ' to approximately half a million sterling—many times the amount available at that period for the conduct of agricultural research in this Dominion. A sounder fundamental knowledge would have allowed each of these bogeys to be dispelled at once ; it is conceivable that under such circumstances the spot diagnoses upon which they were based would never have been made.

Similar examples are numerous and need not be called upon ; the moral, however, should be more obvious than it apparently is. There is a tendency in some university faculties of agriculture to dilute the curriculum with the teaching of the habits of horses and the intricacies of farm machinery in the hope of producing ' good extension officers.' Attention seems no longer to be fixed on raising the standards of scientific understanding which, incidentally, would reveal a lack of sound knowledge of the type which might profitably be extended to the practice of agriculture. The point of view, already prevalent in other fields of applied science, is seemingly no longer guided by the simple belief that application flows easily and naturally from a complete understanding of the underlying phenomena. In an attempt to hurry, a great deal of effort is being dissipated on the investigation of purely local problems which, if pursued far enough, arrive only at a stage from which the lack of fundamental knowledge allows no further progress.

This by no means ends in the realm of animal physiology. But the point need not be laboured further. The tendency to become ' practical ' is, however, a very real problem of agricultural science ; and it is not entirely confined to the antipodes. It has its roots in the teaching, and it may be corrected only by an alteration of outlook in those of our institutions which form the minds of the leaders in the broad field of agricultural endeavour. Research in the more fundamental aspects calls for long-term application and continuity of effort which cannot be fostered by annual grants.

Doctor Thomas Sprat, Bishop of Rochester, Fellow, and early historian of The Royal Society, described ' . . . this various art of experiments ' as having ' . . . many degrees of usefulness, some serving for real and plain benefit without much delight ; some for teaching without apparent profit ; some for light now and use hereafter ; some only for ornamentation and curiosity ' (1667).

We might devote ourselves with more vigour to research ' for light now and use hereafter.' I contend that this is the quickest route to the solution of problems which limit the efficiency of agriculture.

SOME OUTSTANDING PROBLEMS IN AGRICULTURAL SCIENCE IN THE UNION OF SOUTH AFRICA

By A. R. Saunders, D.Sc.(Agric.)

It is rather difficult to deal adequately with this subject in so far as South Africa is concerned for the simple reason that in many instances the problems themselves are not clearly understood and much less definable in rigid terminology. That they are numerous and perplexing everyone who is intimately associated with South African agriculture will readily admit, yet there is still much groping in the dark to find even an approach to some of the difficulties which beset our agricultural industry.

No attempt at exhaustiveness can therefore be made in the remarks which follow and they are confined to those fields of work with which the writer is most closely concerned.

SOIL CONSERVATION

Since soil conservation is basically a question of correct land use in a system of permanent agriculture, its foundations in research are necessarily broad. The primary problem is that of integrating the various branches of farming into a stabilized whole, especially so as regards animal husbandry and crop production, with afforestation playing an increasingly important rôle in certain areas.

Comparatively little, only about 6 per cent, of the Union's land surface is arable, and the prevention or control of soil erosion is therefore, in compass at least, mainly a problem of pastoral farming. Knowledge on the best methods of management of the veld to preserve the natural cover and particularly the most desirable species, is therefore a primary essential. Much valuable work has already been done, but there are still large areas about which information hardly exists and where, unfortunately, erosion has already assumed alarming proportions. This is true of the vast karroid area of the Cape Province, in which erstwhile valuable species of grasses are now conspicuous by their absence. Along its eastern boundaries the karroid vegetation is steadily encroaching into the grass-veld while in the west the desert marches slowly but relentlessly on into the great Karroo. Here is a problem which brooks no delay in its solution if disaster is to be avoided.

More specifically there are such questions as the erodibility of different types of soil and the factors which affect it; the influence of type of cover—whether grassland, low scrub or forest—on run-off and erosion; the effect of method of cultivation and rotational practice on the amount of erosion from arable soils, and a host of minor considerations. More

extensive studies are needed on the amount of run-off from different types of soil with varying slope and under different surface treatments, while much also remains to be learned about mechanical and other methods of controlling erosion, such as contour banks, strip-cropping, etc.

FUNDAMENTAL SOIL PROBLEMS

A clear understanding of our soil is basic to all agricultural science and practice, for if we can save the soil and obtain from it a fair reward for our labours all will be well.

South Africa is not richly endowed as regards the productivity of its surface soil, though lower down into its earth there seems to be some considerable wealth ! We have our own characteristic soil problems, of which the following are the more prominent examples :—

(*a*) A widespread deficiency of available phosphates.
(*b*) A comparatively low organic matter content and extremely rapid oxidation of the organic matter in cultivated soils due to high soil temperatures and other contributory factors.
(*c*) A rapid deterioration in the structure of most soil types under cultivation, followed by a steep decline in productivity.

These problems call for thorough-going research into the mechanism of fixation of P_2O_5, the fixing ability of various types of soil, the nature and function of the colloidal fraction responsible for fixation, soil physics, geochemistry, and, above all, into the still open and extensive field of soil microbiology.

PASTURE RESEARCH

The veld is the mainstay of pastoral production in South Africa and the main fabric of pasture research is, and must in future remain, concerned with it. Management investigations to maintain the sward and preserve desirable species, though far advanced, need to be expanded, particularly in the drier parts of the country.

Much of the veld has been destroyed or has deteriorated through mismanagement, and the reclamation of worn-out and abandoned ploughlands presents a vital and important problem, including as it does reseeding, cultural treatment, contouring, planting of trees and bushes, collection of seed of veld grasses and grazing management. One type of deterioration especially difficult to rectify is the replacement of the grass vegetation by dense bush. Bush encroachment is doubly serious because not only is the carrying capacity of the veld reduced to a greater or less extent but in extreme cases the density of growth becomes such that neither man nor grazing animal can penetrate into the bush.

Although much has been said about the advantages of ley farming (based almost exclusively on overseas data) the information available on this practice in South Africa is, to say the least, extremely scanty. How rapidly and to what extent ley crops in the rotation are a means of restoring soil productivity, the best crops to use as leys, the levels of nutrition they require and the most profitable methods of utilizing them are all questions to which no answers can yet be given. The truth is that our agriculture suffers from a serious dearth of suitable ley crops, both grasses and legumes,

and the finding or development of such crops is an urgent task to which most earnest and untiring effort should be devoted.

Production of grass seed for reclamation or restoration purposes constitutes a problem by itself and requires a study of the seeding habit of different species, methods of harvesting, cultural treatment for seed production, fertilizer needs and methods of establishment.

Another matter for inquiry in different parts of the country and on different soils is the removal-replacement ratio of the veld, i.e., the amount of herbage which can be removed without impairing the productivity of the soil. Closely linked with this question is the fertilizer needs of the veld. Whereas cultivated soils generally respond to nitrogen only under conditions of irrigation or winter rainfall and in parts of the summer rainfall area receiving a relatively high precipitation, the grass-veld invariably reacts to the application of nitrogenous fertilizers. This reaction is sometimes accompanied by surprising changes in the species composing the vegetation and calls for penetrating investigation.

AGRONOMIC PROBLEMS

In spite of the comparatively small percentage of arable land, crop production occupies a pivotal position in our agricultural economy. This fact has been very forcibly brought home to us (somewhat to the embarrassment of certain economists) at the present time of food shortage in the Union as the world over.

The crucial problem is that of higher production per acre or per morgen. Ample experimental evidence is at hand to prove that despite the limitations of rainfall greatly increased production per unit area of cultivated land is possible if better methods of cultivation are applied and if the productivity of the soil is enhanced. In the last point lies the crux of most of our agronomic difficulties.

A solution of these difficulties must inevitably be sought in several fields of scientific research. A few soil problems have already been referred to. Their investigation cannot be divorced from agronomic experiments on crop suitability, rotational system, cultural practice, green-manuring, ley farming and many other factors.

Several ideas have recently been advanced to the effect that, amongst other things, so-called trash farming or ploughless culture and the use of compost would be sure cures for all our agronomic ills. It is hardly necessary to state that they are not, and the unfortunate and unnecessary controversies to which these views have given rise have retarded rather than advanced sound agronomic research. These ideas cannot be ignored, however, and the problem is to determine to what extent the plough can be dispensed with and under which conditions the use of compost is economically and scientifically justified, not merely in terms of crop yields but in terms also of vital influences on the soil itself.

Whatever else present and future experiments might reveal as helpful means of maintaining soil fertility and restoring exhausted soils, one thing is certain and that is that we ought to know much more about the effects of various crops on those which follow and on the life and body of the soil. Ley farming affords a ray of hope for some basis on which crop

production can be stabilized, but until suitable crops readily establishable from seed are available for the purpose, a solution along these lines is more a matter of wishful thinking than agronomic practicability.

Concurrently with soil depletion, weed encroachment and multiplication on cultivated lands is becoming ever more serious, so much so that large tracts of land have been abandoned to certain types of weeds which the farmer finds it impossible or uneconomical to control. Water-grass or nut-grass alone (*Cyperus* spp.) causes losses in maize yields of probably tens of thousands of tons every year and a thorough search after methods of control through the use of selective chemicals, cropping systems and cultural practices is overdue.

Irrigation farming provides its own particular and often baffling problems for the soil scientist and agronomist. The same soil and crop type or variety usually react quite differently to irrigation as compared to dryland culture. The accumulation of harmful salts in the surface soil is a problem of major scientific and economic significance and on its solution depends the very existence of some of our irrigation schemes. Changes in soil reaction, structure and life under irrigation are, as yet, little understood, and much more requires to be known about the movements of soil moisture, colloids and solutes in irrigated soils as well as the effects of fertilizers, especially green-manure and other organic substances.

Finally, there is the need for crop varieties better adapted to South African conditions. With the exception of the sorghums and *Vigna* species all our main crops are of foreign origin and many of them leave much room for improvement in adaptation to climate and soil. But this is essentially a problem of plant breeding.

PLANT BREEDING

Hardly any crop grown in the Union can be said to be satisfactory in all respects and although the task of the plant breeder is a never-ending one this is no reason for defeatism. In the interests of brevity some of the main plant breeding problems may be listed as follows :—

(i) Maize more resistant to drought and of higher yielding capacity, for ensilage as well as grain. In this connexion an obvious advance would be the production of crossed seed from self-fertilized lines.

(ii) Wheat with greater resistance to rust and other diseases, better baking quality and higher yields. Three main classes are required, viz., types with comparatively early maturity for the winter rainfall area of the south-western Cape Province, others with a long vegetative period for the eastern Orange Free State wheat area and lastly, varieties suitable for production under irrigation.

(iii) Potatoes resistant to virus diseases and blight, especially early blight (*Alternaria*) and adapted to high temperature conditions.

(iv) Kaffircorns resistant to the phanerogamic parasite (*Striga lutea*) and of sufficiently short stature to permit of harvesting by combine.

(v) Tobacco adapted to various soil types and of higher yield, greater resistance to disease, and better quality.

(vi) Longer lived and more drought-hardy lucerne for dryland culture.

(vii) Erect cowpeas for harvesting by machinery and perennial types for ley purposes.
(viii) Non-shattering soya beans suitable for combine harvesting.
(ix) Drought and disease resistant groundnuts of higher yielding capacity.
(x) Drought-hardy, disease resistant common beans.
(xi) Better pasture grasses for hay and grazing, especially perennial types readily establishable from seed and of good nutritive value for use as temporary leys.

Several other agronomic crops require the plant breeder's attention, not to speak of fruit and vegetable crops. There is ample work for teams of breeders, work which in the light of the results obtained from a few individual efforts seems fully justified.

ANIMAL HUSBANDRY

The basic problem, around which all aspects of animal husbandry centre, is that of higher production within the limits of a greatly varying environment. It resolves itself into two main phases :—

(*a*) better feeding and management to suit the high-producing exogenous breeds of livestock and
(*b*) the breeding of improved types better adapted to the environment —unfavourable in varying degree—which characterizes most of the ranching areas.

Better feeding must naturally be based on nutritional research and determinations of the food value of home-grown feedstuffs, including the natural vegetation. The influence of seasonal fluctuations in the quantitative and qualitative nutritional value of the natural vegetation upon the development, production and reproduction of livestock is a matter of special importance. Intimately associated with it is the question of the effect of soil deficiences and fertilizer treatment on the nutritive value of crops and pastures.

The breeding problem is mainly one which concerns extensive farming. A first requirement is a study of the reaction of breeds and of types within breeds to climate, especially high temperatures. Though valuable work has already been done in this direction it has by no means reached finality. On the animal genetics or breeding side hardly any critical data are available concerning the breeding value of indigenous livestock, especially native cattle. After centuries of natural selection under exacting conditions of climate and disease prevalence there must unquestionably have been created a large reservoir of valuable genetic material, yet no attempt has been made to capitalize this material in long-term scientific breeding experiments.

Ranch cattle are, however, not the only stock requiring the attention of the breeder. Dairy cattle, sheep and pigs also offer wide scope for improvement, and there seems no sound reason why animal breeders in South Africa should not aim at the ultimate production of entirely new breeds to suit the peculiar conditions of the country.

The foregoing brief remarks have no more than hinted at some of the major problems with which agricultural science in South Africa has to deal. The paramount issue for the country to face is that because of the poverty of its soil, the scantiness and unreliability of its rainfall, and the great variation in climate and topography, it has to devote relatively far greater energies to agricultural research than most other countries.

AGRICULTURAL AND VETERINARY RESEARCH IN SOUTH AFRICA

A Statement by Heads of Divisions

The Department of Agriculture of the Union Government is responsible for the control and organization of agricultural research in South Africa. The activities of the Department are decentralized and vested in the various Divisions, Institutes and Agricultural Colleges. The Secretary for Agriculture is responsible for the co-ordination of the activities of these sub-departments.

To appreciate the comprehensive scope and ramifications of the Department's activities brief statements are set out in the attached appendices.

APPENDIX	1	is a diagrammatic chart of the organization of the Department (see chart facing page 144).		
APPENDIX	2	sets out the functions of		The Division of Veterinary Services
APPENDIX	3	,,	,,	,, The Division of Entomology
APPENDIX	4	,,	,,	,, The Locust Control and Research Organization
APPENDIX	5	,,	,,	,, The Division of Botany and Plant Pathology
APPENDIX	6	,,	,,	,, The Division of Horticulture
APPENDIX	7	,,	,,	,, The Division of Chemical Services
APPENDIX	8	,,	,,	,, The Western Province Fruit Research Station
APPENDIX	9	,,	,,	,, The Dehydration and Cold Storage Laboratory
APPENDIX	10	,,	,,	,, The Low Temperature Research Laboratory
APPENDIX	11	,,	,,	,, The Dairy Research Institute
APPENDIX	12	,,	,,	,, The Agricultural Research Institute
APPENDIX	13	,,	,,	,, The Stellenbosch-Elsenberg College of Agriculture
APPENDIX	14	,,	,,	,, The Division of Agricultural Education and Research
APPENDIX	15	,,	,,	,, The Division of Soil Conservation and Extension
APPENDIX	16	,,	,,	,, The Division of Economics and Markets

APPENDIX 2

THE DIVISION OF VETERINARY SERVICES

1. The Onderstepoort Veterinary Research Institute

The most important work of the Division is carried out at its Institute at Onderstepoort. The Institute boasts a number of well equipped laboratories and has some 7000 acres of land at its disposal. The functions of the Institute can be summed up under the following headings :—

(i) research
(ii) preparation of vaccines and remedies
(iii) service to farmers
(iv) teaching
(v) publications

each of these will be discussed briefly.

(i) Research

Onderstepoort was originally intended as a research station. Research has always remained its main function. Every phase of veterinary science is included in its programme, while certain aspects of animal husbandry are also being studied. In general, it may be said that ' the animal in health and disease ' forms the subject of all investigations.

For administrative purposes the work has been divided into sections, but there is no sharp cleavage between these. For the purpose of this review it will be convenient to study each section in turn.

(*a*) *Section of protozoology*—Here diseases caused by protozoa are studied. Most important of these are the trypanosome and the piroplasm diseases. The former group includes nagana of cattle and dourine of horses, the latter East Coast fever of cattle, redwater and anaplasmosis of cattle, biliary fever of dogs and horses, etc. Scientific control of these diseases only became possible as a result of the research work carried out at Onderstepoort and elsewhere. Globidiosis has become a disease of first importance.

(*b*) *Section of virus diseases*—Some of the most important diseases of animals in South Africa fall under this heading—horsesickness, blue-tongue of sheep, heartwater of cattle, sheep and goats (rickettsiosis), rabies (hydrophobia) of dogs, meercats and other animals, and so on.

(*c*) *Section of bacteriology*—This section studies diseases caused by bacteria, e.g. anthrax, black quarter (or quarter evil), tuberculosis, contagious abortion, mastitis, paratyphoid, botulinus.

(*d*) *Section of parasitology*—The internal and external parasites of our domestic animals are studied in this section, also the insects and arthropods which carry diseases.

(*e*) *Section of surgery and obstetrics*—The research programme of this section includes the problem of sterility in cattle, sheep and horses. The study of this problem has led to extensive investigations on the sex physiology of sheep and cattle.

(*f*) *Section of medicine and therapeutics*—Here the treatment of the various diseases of animals is being studied. New drugs are assessed. Special

attention is devoted to the treatment of nagana and other protozoal diseases.

(*g*) *Section of hygiene*—Problems in connection with meat and milk hygiene are being studied.

(*h*) *Section of pathology*—This section collaborates with other sections in the study of the macroscopical and microscopical changes in various diseases. A special study has been made of the pathology of diseases of the bones, diseases of the blood, of tumours in their many forms, etc.

(*i*) *Section of anatomy*—A special study is made of cytology. Microscopical technique is receiving special attention.

(*j*) *Section of zootechnique and meat research*—The research work of this section is carried out largely at the sub-station Armoedsvlakte, near Vryburg. The main theme of this work is ' the influence of environment on indigenous and imported breeds of cattle.'

In the meat research laboratory at Onderstepoort, meat is being studied in all its aspects—slaughter of animals, treatment of carcasses, chilling, freezing, studies of the properties of meat, etc.

(*k*) *Section of physiology*—Much attention has been devoted to the problem of photosensitization and bioclimatology. The digestion of the ruminant is receiving attention, and the action of hormones is also being studied.

(*l*) *Section of pharmacology and toxicology*—The poisonous plants of South Africa form the main theme in the research work of this section. In a separate sub-section the poisonous principles (alkaloids) of some of these plants are being isolated and their properties and constitution determined.

(*m*) *Section of biochemistry and nutrition*—In the section of biochemistry and nutrition, the determination of the nutritional value of South African feeding stuffs is undertaken as well as studies in mineral metabolism. The section also assists with the biochemical problems as they arise in the sections of physiology, bacteriology, medicine, etc.

(*n*) *Section of chemical pathology*—Work on the chemical components of blood and other tissues, and on the pigments of the animal body is proceeding. Investigations on the many problems connected with dipping are also undertaken.

(*o*) *Section of poultry*—All diseases of poultry are being studied.

(*p*) *Section of wool*—A separate and very well equipped building accommodates this section. Comprehensive study of the properties of South African wool, wool fat, etc., are being undertaken.

(*q*) *Section of statistics*—All the results obtained in the various sections are checked by statisticians to see if they are sound.

(ii) Preparation of vaccines and remedies

This second important function of Onderstepoort is inextricably bound up with the first. At Onderstepoort research and vaccine production go hand in hand. Whenever the results of research indicate a possible improvement to a vaccine or remedy, that improvement is immediately made. This is perhaps the greatest advantage in combining the ' factory side ' of veterinary science—the manufacture of vaccines—with the research side.

The following table indicates the type of vaccine and remedy prepared

at Onderstepoort and the approximate quantities issued during the financial year 1944–45 :

anthrax	5,948,980	doses
black quarter	1,383,315	,,
bloedpens	128,820	,,
bluetongue	2,303,736	,,
contagious abortion	79,988	,,
gallsickness	181,506	,,
horsesickness	369,190	,,
paratyphoid	324,260	,,
fowl typhoid	559,385	,,
fowl pox	797,950	,,
nodular worm remedy	19,490,100	,,
tetram	5,200	gallons
blowfly spray	45,089	,,
carbon tetrachloride	3,765	,,

(iii) Services to farmers

Apart from the supply of vaccines, there are other services which Onderstepoort renders to farmers, e.g., the examination of blood smears and other specimens from sick or dead animals. The advantage to the farmer is obvious, while the research worker too derives benefit from these examinations in that they bring to his notice conditions, perhaps hitherto unknown, which occur in the country. Material is also examined for the presence of toxic substances.

(iv) Teaching

The veterinary course takes five years after matriculation and leads to the degree of Bachelor of Veterinary Science (B.V.Sc.), which is conferred by the University of Pretoria. The degree of D.V.Sc. can also be obtained by submitting a thesis provided at least two years have elapsed after the B.V.Sc. degree.

(v) Publications

Since 1933 Onderstepoort has issued its own journal, known as the 'Onderstepoort Journal of Veterinary Science and Animal Industry.' Two volumes appear annually. This journal is sent to institutes and scientists all over the world.

More popular articles suitable for farmers are published from time to time in 'Farming in South Africa,' the official publication of the Department of Agriculture. Many separate pamphlets are also issued.

2. Veterinary Research Out-stations

Onderstepoort also controls a number of out-stations. These undertake more specialized research and are situated in each of the four Provinces to study local problems. Their location and work are indicated below.

(i) Allerton, near Pietermaritzburg, has a well-equipped laboratory. It serves as a subsidiary centre to the main Institute. Research work, particularly on poultry diseases, is carried out. Some vaccines are prepared.

(ii) Armoedsvlakte and Biesiesvlakte are two farms, some 14,000 acres in extent, near Vryburg in the Cape Province. These were originally acquired for research into 'Lamsiekte.' Since the solution of this problem they have been used to study diseases and nutrition of cattle. The main project for some years has been the study of environment on indigenous and imported breeds of cattle.

(iii) Bestersput is a farm of 6000 acres in the Furesmith district of the Orange Free State. This station is used to study and experiment on sheep. Worm infections are studied in particular.

(iv) The Nagana Research Station is situated in the Umfolosi district of Northern Zululand. Here the tsetse fly, its characteristics and destruction, are studied. This station controls bush clearing to prevent migration of the fly. It also supervises the eradication of game—the carriers of Nagana.

3. Field services

The field services of the Division administer the Stock Diseases Acts. They are always in close contact with the Institute and report problems in need of investigation.

4. Further extension

The activities of the Division have increased to such an extent that the Government has under consideration the recommendations of a recently appointed commission materially to augment the facilities and staff of the Division.

APPENDIX 3

DIVISION OF ENTOMOLOGY

1. Functions

The functions of the Division of Entomology comprise—

(i) Research and advice on the control of all insect pests except those directly concerned with human and animal health.

(ii) Pest suppression and prevention (plant import regulation, nursery inspection and the control of the inland movement of plants and plant commodities).

(iii) Advice to the Department with regard to policy on matters relating to insect pests so that administrative and legislative measures to control them may be introduced.

(iv) The study and exploitation of natural enemies of noxious plants such as prickly pear and other *Opuntias*.

2. ORGANIZATION

The Division is an independent branch of the Department of Agriculture. Its administrative section is located in Pretoria in close touch with departmental headquarters and other Divisions and State Departments. Its research functions are conducted wherever the most suitable facilities for any particular problem or subject exist.

3. A PLANT REGULATORY SERVICE is conducted through—

(*a*) Plant inspectors stationed at the main seaports and at such inland transport centres as may be necessary.
(*b*) Itinerant plant and nursery inspectors.
(*c*) Specific pest suppression where necessary.
(*d*) The administration of the Agricultural Pests Act.

APPENDIX 4

LOCUST CONTROL AND RESEARCH ORGANIZATION

1. FUNCTIONS

This section wages anti-locust campaigns whenever necessary and at all times carries out research on the two locust species occurring in the Union.

2. LOCATION

The headquarters of the control organization and the principal laboratory are situated in Pretoria. In addition there are two substations—one in the Brown locust outbreak area at Middelburg in the Karroo, the other near Kenhardt in the North-western Cape.

3. RESEARCH

Improved methods of destruction, investigation of new poisons, and detailed biological studies are carried out at the Pretoria Laboratory.

At the outstations and in the field the origin and causes of periodic increases in the locust population are studied so that more rational preventive control of outbreaks in their initial stages can be attempted. This involves locust population counts over large areas and a close study of climatic and ecological conditions throughout the outbreak area.

4. STAFF

The permanent staff comprises four entomologists and four technical assistants. Experienced temporary officers are recruited to assist when necessary.

5. LIAISON

Close liaison is maintained with other Divisions of the Department of Agriculture on research problems while the section works with the Department of Defence to control locusts from the air.

At the present time two officers of the Department are co-operating with personnel of other governments in a first attempt at the preventive control of the red locust in its outbreak area in Tanganyika.

APPENDIX 5

DIVISION OF BOTANY AND PLANT PATHOLOGY

The function of the Division of Botany and Plant Pathology is the study of plants, indigenous and exotic, with special reference to their rôle in agriculture. This work is controlled and organized by the chief of the Division.

The Division comprises two sections :

1. The Botanical Section

The work of this section includes :—

(*a*) The study of systematic botany. To this end four herbaria are maintained at Pretoria, Durban, Grahamstown and Kimberley. In these herbaria specimens of the phanerogamic flora of Southern and Tropical Africa, including plants of economic importance, are collected and preserved.

(*b*) Botanical survey. Headquarters are at Prinshof, Pretoria. This section makes an ecological study of types of vegetation in the various phytogeographical areas, and of the relation of natural vegetation to agriculture.

(*c*) The control of noxious weeds and poisonous plants by chemical and other means. This work is carried out in Grahamstown.

(*d*) The maintenance of ' veld reserves.' The veld reserves are maintained for the study of Karroo plants. At Fauresmith there is a laboratory for the study of plants of the upper Karroo, their feeding value, drought resistance, etc. Indigenous fodder bushes are propagated. Another station of this type is at Worcester.

2. The Pathological Section

The work of this section includes :—

(*a*) The study of plant diseases, their cause and prevention. For this investigation pathological laboratories are maintained at—

(i) Pretoria—the main project at the present is the study of potato viruses.

(ii) Durban—the study of the diseases of cane and other subtropical plants.

(iii) Nelspruit—the study of diseases of citrus, tomatoes, avocadoes, mangoes, and other subtropical fruits.

(iv) Pietermaritzburg—the study of diseases of wattles and other forest trees.

(v) Buffelspoort—an experiment station for field investigations.

(*b*) Cryptogamic botany. A herbarium of cryptogamic plants—chiefly fungi—is maintained, while a systematic study of fungi especially those parasitic on cultivated and indigenous plants is made.

APPENDIX 6

DIVISION OF HORTICULTURE

The Division of Horticulture is responsible for research into the production problems of the fruit, vegetable and flower industries of the Union, excluding the western section of Cape Province known as the winter rainfall area. The Division has established and controls experiment stations in various parts of the country.

1. Pretoria

The head office of the Division is located in Pretoria. Besides being the administrative headquarters of the Division, modern research laboratories are also maintained. The research field covered by this staff deals largely with citrus crop production problems.

2. Vegetable research station

Just outside Pretoria the vegetable research station has been established. This station deals with vegetable production problems, and with the genetic aspects of seed production.

3. Subtropical horticultural research station

This station is located at Nelspruit. It deals with all horticultural problems of the Eastern Transvaal. By virtue of the climatic conditions of the locality the crops being dealt with are citrus, semi-tropical fruits and vegetables.

4. Pineapple research station

This small station is at Bathurst, the centre of the pineapple industry in the Eastern Cape Province. Field experiments with pineapples, such as the nutrition and breeding of new varieties, are carried out.

5. Vaalhartz experiment station

This station is at Andalusia in the middle of the largest irrigation scheme in the Union. Though this station is not actually controlled by the Division, two officers of the Division are stationed there to conduct investigations into the production problems of deciduous fruit, grape vines and vegetables.

6. Research station, Upington

This station is also not directly controlled by the Division, which has two of its officers stationed there to conduct investigations in connexion with the production problems of the sultana grape and fruit growers in the area.

7. Potchefstroom

The Division also stations one of its professional officers at the College of Agriculture at Potchefstroom in the Transvaal. This officer deals with fruit and vegetable problems under Highveld conditions.

8. Field Work

In order to deal with field problems and to conduct field trials under the different climatic conditions of the Union, the Division has officers stationed in various important localities. Here no fully equipped laboratories are available, and the purpose is essentially to connect up through field trials with the more fundamental research being conducted in the larger centres. Such officers are stationed at Oudtshoorn in the South-Western Cape Province, at Joubertina in the Langkloof, Eastern Cape Province, at Port Elizabeth in the Eastern Cape Province, and at Stellenbosch-Elsenberg College of Agriculture.

APPENDIX 7

THE DIVISION OF CHEMICAL SERVICES

The Division of Chemical Services came into being about 1924 when various chemical units in government service were combined into one group to centralize the chemical work required by various government departments.

The Division maintains four laboratories on its own account at Pretoria, Johannesburg, Cape Town and Port Elizabeth. The latter laboratory was closed as a war-time measure but it is intended to re-open it at an early date. The Division also shares with Rhodes University College the control of the Leather Industries Research Institute at Grahamstown, the director being an officer of the Division. It has officers at the Cedara College of Agriculture, Grootfontein College of Agriculture, Vaalhartz Experiment Station and at the offices of the Chicory Control Board. A sublaboratory is stationed at the Government Printing Works to study the problems of the printing trade. The Division co-operates with other divisions of the Agricultural Department to enable field experiments to be carried out at different centres or institutions.

The activities of the Division cover a wide field. It undertakes work for most other government departments and it has been found expedient to develop different sections. Regulatory work must to some extent be provided for at more than one centre, so that no hard and fast demarcation between the work of centres or sections is possible. The allocation of work is approximately as follows :—

Pretoria

(*a*) Soil survey, including pedological research.
(*b*) Soil fertility, including reclamation.
(*c*) Analytical : analyses of fertilizers, manures, composts, waters, feeding stuffs, etc. ; analyses of minerals for Geological Survey.
(*d*) Industrial : insecticides ; salt, paints, corrosion, etc. ; foodstuffs ; inks, type metals and other matters relative to the printing industry.

Johannesburg

(*e*) Foods and drugs : control and research.
(*f*) General : including customs work and mineral and water analyses.
(*g*) Toxicological work.

Cape Town

(*h*) Wine and spirits : regulatory and research work.
(*i*) General : similar to (*f*) above, also regulatory work under Agricultural Export Acts and Foods and Drugs Act.

Port Elizabeth

(*j*) General : mainly control of export fruit.

APPENDIX 8

WESTERN PROVINCE FRUIT RESEARCH STATION, STELLENBOSCH, CAPE PROVINCE

This institution was established in 1935 as a special division of the Department of Agriculture and consists of research laboratories at Stellenbosch (including a special laboratory for biological control of codling moth), two experimental stations, viz., Groot Drakenstein Experimental Farms and the Paarl Viticultural Station, as well as substations at Ceres, Worcester and Robertson. A large number of permanent experimental plots are maintained on a co-operative basis in the various fruit growing areas.

The technical staff is organized into nine sections, viz., horticulture, viticulture, biochemistry, entomology, plant pathology, genetics, plant physiology, agricultural meteorology and fruit and vegetable processing and by-products.

1. Functions

The functions of the Institution include research and extension work in connexion with deciduous fruit and table grape production and processing in the Western Cape Province.

2. Extension activities

Extension work amongst fruit growers is carried out by means of correspondence, publications, addresses to Farmers' Associations, visits to farms and an Annual Farmers' Day.

The extension work also includes advice to canners, dried fruit packers and processors generally. Many hundreds of circulars have been distributed for this purpose.

3. Research activities

The research activities of the Institution cover the complete range of growth, production and processing of deciduous fruit, as well as the

processing of vegetables. The main projects under investigation can be briefly summarized as follows :—

(i) *Climatic studies*

(*a*) A survey of climatic components in the Western Cape Province in relation to fruit production and the zoning of the area into climatic groups with reference to culture of deciduous fruit.

(*b*) Variety suitability and the behaviour of specific varieties under known conditions of the climate. For this purpose there has been established a completely equipped central Meteorological Station at Groot Drakenstein and twelve substations at strategic points in the fruit growing areas.

(ii) *Soil distribution and soil utilization*

The distribution and classification of the soils of the fruit growing areas with reference to their adaptability to the culture of deciduous fruit and vines.

(iii) *Studies on root stocks and varieties*

(*a*) Stocks : the whole question of the suitability of root stocks of deciduous fruit and vines, in relation to the special environmental conditions existing in this region, is being investigated.

(*b*) Varieties : studies on varieties are largely associated with suitability of varieties under our environmental conditions. This entails the breeding of new varieties more suitable to local conditions as well as the use of special sprays and cultural treatments to combat the deleterious influence of high winter temperatures.

(iv) *Investigations on cultural treatment*

Aspects on cultural treatment which require considerable elucidation and which largely aim at producing fruit of the highest quality at the lowest cost, are the following : Methods of budding and grafting, planting and siting of orchards, pruning and thinning, pollination and general orchard management.

(v) *Studies on plant nutrition and soil management*

From the point of view of plant nutrition, the main aspects of investigation are interrelation and level of nutrient elements. The distribution and function of these in the plant and the methods of diagnosis of deficiency with particular reference to minor elements. The question of moisture requirements is being studied in some detail.

(vi) *Biochemical investigations*

These include the keeping qualities of fruit and the influence of environment and growth habit on the post-picking behaviour of deciduous fruit under various conditions of storage and transportation.

The types of breakdown which occur during the disposal and processing of fruit, with particular reference to its manner of production is intensively investigated.

(vii) *Pests and diseases*

Deciduous fruit production is subject to a host of pests and diseases which cannot be described in detail here. The method of study is largely from the point of view :—

(*a*) of the bionomics of the insect or organism, its life history and ecological relationships, and

(*b*) the control of disease. This is so far largely a matter of chemical treatment. Selection of varieties for resistance is in progress.

(viii) *Processing of fruits and vegetables*

It has been established at this institution that there is a close relationship between environment and cultural treatment on the one hand and the utilization of the fruit on the other. In these studies particular attention is paid to storage and pre-treatment of the fruit and processing methods.

4. PUBLICATIONS

Although war conditions have greatly hampered publications, some 50 scientific papers and bulletins and 120 farmers' bulletins on fruit problems are available from the institution. An exchange list will be sent on request.

APPENDIX 9

THE DEHYDRATION AND COLD STORAGE LABORATORY

The Division of Dehydration and Cold Storage is situated in Cape Town, with a subdivision in Johannesburg. One technical officer is stationed at each of the dehydration factories to control production. The division has a fully equipped and up-to-date laboratory whose main functions are :—

(i) *Vegetable dehydration*

(*a*) Research and development for the dehydration industry in the Union including the design, locality and erection of factories and the supervision and technique of the industrial process.

(*b*) Investigation of the packing and storage of dehydrated products.

(ii) *Fruit dehydration*

Research and technical development of the fruit dehydration industry, and direct technical advice.

(iii) *Milk, eggs, etc.*

Direct technical assistance to the firms producing dried eggs, milk, etc.

(iv) *Chicory*

(*a*) Technical advice to the Chicory Control Board in regard to the drying of the roots.
(*b*) Design and construction of a pilot plant for the investigation of the commercial drying of chicory.

(v) *Grain*

(*a*) Research and technical development of grain drying in the laboratory.
(*b*) Erection of pilot plant and trial tests on grain drying on a commercial scale.

(vi) *Cold storage*

(*a*) Inspection of cold stores and the scrutinizing of plans and specifications for new cold stores, and for the reconstruction or additions to existing cold stores.
(*b*) Technical control of machinery, and of the conditions of storage of foods, e.g., the specification of temperature for eggs, meat, fruit, etc.

APPENDIX 10

LOW TEMPERATURE RESEARCH LABORATORY, CAPE TOWN

The Low Temperature Research Laboratory is a Division of the Department of Agriculture concerned with the preservation and transportation of foodstuffs. Originally established to investigate the cold storage and transportation at low temperatures of deciduous and citrus fruit intended for export overseas, the scope and functions of the laboratory have been broadened recently to include methods of preservation of all foodstuffs.

The laboratory is now equipped to investigate methods of chilling, canning and dehydration. The nutritional value of foodstuffs and food technology are studied in detail. Further expansion is contemplated to provide facilities for the investigation of preservation of foodstuffs in the frozen state—particularly fish.

The laboratory is very well equipped with the most modern facilities for investigational work. Post-war expansion is likely to be considerable. Prior to the war the laboratory published an annual report of activities and publication will be resumed soon.

APPENDIX 11

DAIRY RESEARCH INSTITUTE

The Dairy Research Institute falls under the control of the Division of Dairying. The laboratories were erected in the grounds of the University

of Pretoria so that the Institute could work in close co-operation with the departments of animal husbandry, veterinary science, chemistry and bacteriology of the University. The Institute receives a grant of £1000 per annum from the Dairy Industry Control Board.

The functions of the Institute are to :—

(*a*) Conduct research on the production of raw materials and to study the feeding, care, management of, and the control of disease in dairy cattle.

(*b*) Undertake investigations in regard to the manufacture of dairy products. Problems experienced by manufacturers are referred to the Institute for investigation.

(*c*) Analyse dairy products together with the water and ingredients used in their manufacture. Fees are charged for this service.

(*d*) To prepare bacteriological cultures for factories. This work is somewhat specialized and cannot usually be undertaken in factories.

APPENDIX 12

THE AGRICULTURAL RESEARCH INSTITUTE, PRETORIA

The agricultural Research Institute was established at Pretoria as a division of the Department of Agriculture in January 1940, through the incorporation of the Faculty of Agriculture of the University of Pretoria into the Department. It consists of the departments of animal husbandry, agronomy, agricultural chemistry, biochemistry, dairying, veterinary science, plant pathology and microbiology, plant breeding, poultry husbandry, agricultural economics, entomology, grassland research and agricultural engineering.

The objects of the Institute are twofold :—

1. Educational

The Institute is equipped for the general and specialized training of students leading to the B.Sc., M.Sc. and D.Sc. degrees in agriculture and agricultural engineering.

The educational work falls under the jurisdiction of the Council of the University of Pretoria.

2. Research

Investigations are conducted primarily on problems related to agricultural practice in the summer rainfall area of the Union. Since the departments of the Institute embrace practically the whole field of agricultural science, its staff is placed in the unique position of being able to study all phases of agriculture and of seeing the problems of the industry from different points of view.

In co-operation with other divisions of the Department of Agriculture a co-ordinated effort is made to assist the farming community and to develop the industry.

The research work forms the basis on which the training of future professional and technical officers in agriculture rests.

An experiment farm, some 1900 acres in extent, forms an important part of the Institute. This is used for research work, the variety of experiments conducted contributing valuable information towards the solution of many farming problems. While the work is mainly of a fundamental nature provision is made for testing the information obtained on a practical scale.

The Institute also conducts citrus research on two estates in the Eastern Cape Province. It receives annual grants from private citrus companies for this work.

A summary of the work done is given in the annual report of the Institute.

A description of the courses given may be found in the calendar of the University of Pretoria.

APPENDIX 13

THE STELLENBOSCH-ELSENBERG COLLEGE OF AGRICULTURE

The Stellenbosch-Elsenberg College of Agriculture is responsible for research, extension and the teaching of agriculture in the winter rainfall area. The college has five experimental farms on which work in regard to field crops, animal husbandry, viticulture oenology, olericulture, poultry and dairy husbandry is being conducted.

The teaching work of the college may be divided into two types :—

(i) university teaching which leads to degrees in agriculture—B.Sc., M.Sc. and D.Sc.
(ii) vocational teaching where students and farmers are taught the art, practice and science of farming.

Much of the research work is on problems of actual importance to the farming industry of the winter rainfall area, but fundamental research is also receiving attention.

The number of technical officers working in the various sections indicates the extent of the activities in the various fields of research.

Field husbandry 6, animal husbandry 6, viticulture oenology 8, olericulture 2, poultry husbandry 3, agricultural chemistry 6, entomology 3, plant pathology 4, genetics 3, engineering 1, dairying 1, economics 2, veterinary science 1.

The laboratories at the disposal of the Institution consist of the Agricultural Institution at Stellenbosch, the Oenological Institute at Elsenberg, greenhouses at Stellenbosch, a meatlaboratory at Elsenberg an insectary at Stellenbosch and a pothouse for pot experiments at Welgevallen, Stellenbosch.

APPENDIX 14

DIVISION OF AGRICULTURAL EDUCATION AND RESEARCH

station	situation	researches	equipment	staff
1. Potchefstroom College of Agriculture	Western Transvaal representing Middle veld summer rainfall area of 20″–25″ rainfall	(*a*) plant breeding, maize, sorghum, beans, potatoes, grasses, etc. (*b*) animal nutrition	hothouse, chemical laboratory, digestion crates, field equipment	6 technical officers 3 assistants
2. Grootfontein College of Agriculture, Middelburg, Cape	Cape Province representing Karoo	(*a*) sheep and wool research (*b*) agronomy research; transpiration and duty of water studies	wool laboratory, constant temperature and humidity chambers; chemical laboratory, wool scouring equipment, lysimeters, transpiration drums, field equipment	8 technical officers 13 assistants
3. Glen College of Agriculture	Orange Free State, representing Middle veld of 15″–20″ rainfall	chicory breeding	field equipment; chemical laboratory	1 technical officer 1 assistant
4. Cedara College of Agriculture	Natal representing mist belt	exotic pastures and their economic utilization	field equipment; chemical laboratory	2 technical officers 2 assistants
5. Vaal-Hartz Experiment Station	Northern Cape adjoining the Transvaal on the Vaal-Hartz Irrigation Scheme	(*a*) economic utilization of crops under irrigation for milk and fat lamb production (*b*) agronomic research varieties, fertilizers, duty of water	field equipment	4 technical officers 4 assistants
6. Mara and Messina Experiment Stations	Transvaal representing the Bushveld	beef cattle, breeds and their reaction to climate; growth fertility, resistance to disease, etc.	meteorological equipment	2 technical officers 3 assistants

station	situation	researches	equipment	staff
7. Athole Experiment Station	Drakensberg eastern escarpment representing high rainfall sourveld area	pasture research, economic utilization of natural and exotic pastures; unit experiment beef production	field equipment	2 technical officers 2 assistants
8. Estcourt and Tabamhlope	Natal; Drakensberg eastern escarpment sweet and tall grass area	pasture research and fodder crops	field equipment	3 technical officers 3 assistants
9. Dohne Experiment Station	Eastern Cape representing coastal sourveld area	pasture research, dairy and fat lamb production in unit experiments utilizing winter and summer crops, natural and exotic pastures	field equipment	2 technical officers 4 assistants
10. Kroondal Experiment Station	Transvaal Bushveld tobacco area	tobacco researches, varieties, disease resistance, breeding	usual laboratory and field equipment	4 technical officers 2 assistants
11. Ten small substations	Transvaal, Cape and O.F.S.	variety of problems as outlined in 1-10 above and supplementary to main stations		12 technical officers 15 assistants

APPENDIX 15

THE DIVISION OF SOIL CONSERVATION AND EXTENSION

This division is primarily concerned with interpreting the results of research in farming practice in relation to soil conservation. The Division is therefore not mainly engaged in doing actual research work, though a certain amount of applied research has to be undertaken in the Division's two conservation areas where the reclamation of badly eroded areas is

being attempted. These areas are situated in the Drakensberg and at Vlekpoort. The work being undertaken in these projects may be classified as follows :—

(*a*) Engineering works and mechanical measures for the combating of erosion and the reclamation of eroded areas.
(*b*) The revegetation of eroded areas, in conjunction with (*a*).
(*c*) The recovery of vegetation on overgrazed and depleted areas suffering from surface erosion.
(*d*) The application of the results of agricultural research for the development of conservation farming systems.

In connexion with (*d*) it must be pointed out that this work is not only confined to conservation areas but is also to be extended to selected farms in all districts of the country.

The Drakensberg conservation area comprises 1,000,000 morgen of land between the Mooi and Tugela rivers in Natal. The headquarters are at Estcourt.

The Vlekpoort conservation area comprises 85,000 morgen along the upper reaches of the Vlekpoort river which is a tributory of the Tarka River in which Lake Arthur is situated. This conservation area is to be extended to the whole catchment area of Lake Arthur, which comprises 500,000 morgen.

(Note : a ' morgen ' is equal to about two acres.—Ed.)

APPENDIX 16

DIVISION OF ECONOMICS AND MARKETS

The main functions of the Division of Economics and Markets can be summarized as follows :—

(i) To render certain inland marketing services in nine main centres. Such services are the grading of market produce and issuing of regular reports on prices and quantities.
(ii) To render services of an agricultural economic nature such as crop reporting, reporting on conditions affecting all agricultural production, the collection, tabulation, analysis, and publication of all statistics, both domestic and overseas, which are of value to those concerned with the economic side of South African agriculture. (Material is published in the leading daily and weekly papers as well as in the Division's own monthly journal 'Crops and Markets,' which temporarily appears as a supplement to the departmental publication ' Farming in South Africa.')
(iii) To conduct inquiries into production and distribution problems of an agricultural economic nature—both fundamental problems and those of a specific temporary nature.
(iv) To furnish information to the department and the public on all questions of an agricultural economic nature where and when required.
(v) To advise the Secretary for Agriculture when necessary.

The research work of the Division under (iii) above practically ceased during the war as attention had to be devoted mainly to urgent problems of immediate importance. Work is, however, again being resumed on :—

(*a*) The delimitation of the Union, in co-operation with other branches of the Department, into homogenous farming areas according to physical factors of sufficient economic importance to determine the types of farming of an area.

(*b*) The introduction of a systematic and continuous collection of detailed statistical data of the farming costs and results of a selected but representative number of farmers in each homogenous farming area.

(*c*) Farm management surveys in selected parts of the country, i.e., the obtaining and analysis of certain well defined information about the results of farming, by the process of question and answer.

(*d*) The study of the various processes and the costs connected therewith in the marketing and distribution of various farm products.

In connexion with (*b*), (*c*) and (*d*) above the object of the inquiries are to obtain data on the basis of which :—

(1) those concerned with the production and distribution of farm products could take steps to reduce costs and increase efficiency, and

(2) administrative measures could be initiated or amended to achieve the objects of government policy in connexion with the production, distribution and consumption of farm and food products.

SOME OUTSTANDING VETERINARY PROBLEMS IN SOUTH AFRICA

By Dr P. J. Du Toit
(Director of Veterinary Services, Onderstepoort, South Africa)

Most of the diseases of domestic animals in tropical Africa are also present in South Africa with its sub-tropical climate. In addition, the common European animal diseases flourish in South Africa. No wonder that our country presents such a variety of problems to the veterinarian. In comparison, the other dominions are very fortunate. Australia and New Zealand, thanks to their isolation and the almost complete absence of an indigenous fauna, are comparatively free from animal diseases; and Canada with her severe northern climate is in a most enviable position from a veterinary point of view.

Although many of the most urgent veterinary problems of European countries are just as important in South Africa—I may mention tuberculosis, mastitis, contagious abortion, sterility, etc.—it is not considered necessary to refer to them in this paper. For the purpose of this discussion it will be more profitable to refer to a few problems which are peculiar to South Africa or to the African continent.

TSETSE FLIES

Perhaps the most important veterinary problem of Africa is the *tsetse fly* and the diseases it transmits. If this danger could be removed, vast tracts of land would become available for human settlement and the cattle population of many countries could be doubled or trebled. A campaign against the tsetse has been waged with fair success in many parts of Africa, but the final solution to the problem is not yet in sight. In South Africa at one time it was thought that the tsetse fly could be eliminated from the relatively small fly belts by means of *trapping*, but the Harris trap has been a disappointment on the whole and though it is still considered a useful auxiliary weapon it will never exterminate the fly by itself. *Bush clearing* has also been of great value and hundreds of square miles have been reclaimed in this way; but this method is costly and not applicable everywhere. The *destruction of game* has had to be resorted to in some cases as a means of checking the fly and protecting domestic stock against the ravages of nagana or human beings against sleeping sickness. But it is a method that will always provoke strong opposition and should only be adopted when all else has failed. Now that a direct attack on the tsetse fly has become possible by means of the newer *insecticides* the hope may be expressed that game destruction, as a method of controlling the fly, may become a thing of the past and that, in future, game preservation will be practised on a much larger scale.

The application of these insecticides in the fly belts of Africa has suddenly become a problem of major importance. A fairly large-scale experiment was started last November in one of the smaller fly belts in Zululand, South Africa. An area of approximately thirty to thirty-five square miles in extent, comprising the Mkuzi Game Reserve, was sprayed from the air with a 5 per cent D.D.T. solution in oil. Three sprayings were applied at about fortnightly intervals. The results seemed promising. Although accurative comparative figures cannot be given it seemed as if there was a marked reduction in the number of flies, which persisted for quite a long time. The spraying had to be suspended because of climatic and other factors, but will probably be resumed in July. Meanwhile very valuable information was obtained in regard to the type of aircraft to be used, the equipment for spraying, the rate of delivery of the liquid, the height from which to spray, the area covered, the distribution of the liquid on the ground, the best time of the day to spray, the best method of guiding the aircraft over the area, and a host of other points. Similar experiments are being carried out in other parts of Africa and steps are being taken to ensure that all the information obtained in these experiments is pooled. This work merits liberal support by all governments concerned. If this support is forthcoming on an adequate scale, it may not be long before a solution is found to this problem which has baffled scientists for the past fifty years.

TICKS

Except for the fact that they do not transmit any major disease to man, ticks may be regarded as at least equal in importance to tsetse flies. Not only do they transmit many of the most fatal diseases of our domestic animals and so cause enormous losses, but as external parasites they are also responsible for extensive injuries and great loss of blood.

From an economic point of view East Coast fever of cattle (caused by *Theileria parva*) is still the most serious tick-borne disease in South Africa. An extensive and costly organization has been created for the control of this disease, and the net result has been that the mortality from East Coast fever has been almost negligible in the last few years. But it should never be forgotten that the normal mortality from this disease is near 100 per cent, and that enormous losses would be suffered if the irksome but effective control measures were to be relaxed.

At present the only really satisfactory method of combating ticks is to dip the animals carrying the ticks in a bath (or ' dip ') containing a tick-killing agent. The most widely used substance for this purpose is arsenic, usually in the form of a sodium arsenite solution. It was generally felt that this substance was by no means ideal, being a dangerous poison, but it was difficult to find a substitute which would kill the tick with its hard covering and yet not injure the cattle with their tender skin. But now a new and serious trouble has arisen. In some parts of South Africa the ordinary ' blue tick ' (*Boophilus decoloratus*) seems to have developed a resistance to arsenic and, whereas they used to be regarded as the easiest species of tick to eradicate by means of dipping, they are now completely unaffected by the arsenical dip. This has resulted in a tremendous increase in the number of these ticks and a corresponding increase in the incidence of the diseases they convey. The problem has become one of major importance

in a large portion of the southern and eastern coastal area in South Africa and, according to reports received, it has also appeared in Australia.

And now the new insecticides again seem to be coming to our rescue. Preliminary dipping trials with D.D.T. emulsions and especially with Benzene hexachloride (so-called ' Gammexane ' or ' 666 ') have yielded very encouraging results. Apparently very high dilutions of these substances will kill the ticks (including the arsenic-resistant ' blue tick ') without any damage to the skin of the animals or any of those other undesirable results associated with arsenical dips. We are possibly entering on a new era in the control of ticks and tick-borne diseases. If our expectations are fulfilled one of the greatest obstacles to successful stockfarming in South Africa will be removed.

' LAMSIEKTE ' (BOTULISM)

More than twenty-five years ago Sir Arnold Theiler elucidated the somewhat involved chain of events which led to the appearance of the disease lamsiekte (literally ' lame sickness,' or paralysis) in cattle. He and his co-workers showed how a phosphorus deficiency in the soil and pasture produce a phosphorus deficiency in the animal, thus inducing a craving for substances containing phosphorus (e.g. bones or other carcase material) ; in many parts of the country these bones or carcases become infected with botulinus organisms which produce a potent toxin ; it is this toxin which, when ingested, causes the paralysis and death of the animals.

This chain could be broken at several points. The most satisfactory way was to prevent the disease altogether by feeding substances containing phosphorus to the animals, e.g. bonemeal, and so remove the craving for the infected bones or carcases. This method became very popular and, before the war, large quantities of bonemeal were imported into South Africa. Incidentally the bonemeal was found to have other very beneficial effects on the animals and this added greatly to its popularity.

During the war the supplies of bonemeal dwindled ; imports practically ceased. Concurrently the incidence of lamsiekte increased. Other means had to be found to check the disease ; the chain had to be broken at another link.

Experiments had shown that a very effective toxoid could be prepared which gave a strong immunity against the natural disease. Since two types of *Clostridium botulinum*, types C and D, occur in South Africa, a vaccine had to be prepared against both. This vaccine has been issued since the beginning of this year and promises to be of great assistance in reducing the mortality from this serious disease.

RINDERPEST

South Africa has been free of rinderpest for nearly fifty years, but in Central Africa the disease has been enzootic since it first swept across the continent at the end of the last century. Remembering that rinderpest travelled about 6,000 miles down the length of the African continent in some seven or eight years, the southern states are always inclined to regard the continued presence of this disease in Africa with apprehension. During the first World War the disease showed a tendency to spread southward

from Tanganyika ; so the Union of South Africa sent a team of veterinary officers up north who immunized a belt of cattle between Lake Nyasa and Lake Tanganyika. This measure effectually stopped the spread of the disease towards the southern states and so averted what might have been a national catastrophe.

In 1937 rinderpest again threatened to spread southward. Conferences were held with representatives from all the states concerned. A concerted plan of action was agreed upon and carried out. A fence nearly 300 miles long was erected on the border between Northern Rhodesia and Tanganyika and the game driven away by shooting both north and south of the fence. Immunization of cattle was carried out on a large scale in Southern Tanganyika and an intelligence service maintained in the area. South Africa actually sent a fully equipped field laboratory to Mbosi in Tanganyika to assist in the preparation of rinderpest vaccine. The operations on the 'interterritorial border' (between Tanganyika, Northern Rhodesia and Nyasaland) were financed jointly by the southern states which were threatened by the disease, and the whole scheme functioned with complete success and without a hitch—a glowing example of practical inter-state co-operation.

Rinderpest is still a major problem in Central Africa and its presence there constitutes a danger to the other territories, especially those to the south. To eradicate the disease completely must be the aim of every country. Perhaps the new egg culture vaccine, prepared in Canada by Canadian and American workers, which has so generously been placed at the disposal of other countries by the Canadian Government, will render this task easier.

HORSESICKNESS

In South Africa horsesickness has always been regarded as one of the major veterinary problems. The losses sustained annually by farmers and other horse-owners were very heavy indeed. In many parts of the country horses could not be kept at all because of this disease.

The serum-virus method of immunization introduced by Sir Arnold Theiler alleviated the position to some extent, but only a relatively small number of horses could be treated by this elaborate and costly process. It was not until the mouse brain vaccine was discovered by Alexander that horsesickness lost most of its terror.

This vaccine proved to be a veritable godsend to the countries in the Middle East during the latter phase of the last war. In 1944 horsesickness started spreading down the Nile Valley and threatened the whole of the equine population of Egypt. An appeal for help was sent to South Africa and an officer was sent to Egypt to investigate the position and render what help was possible. As a result of this visit a large quantity of vaccine was despatched to the civilian and military authorities in Egypt. It may be mentioned that this vaccine assisted materially in maintaining the effectiveness of the Ninth Army in the Middle East.

From Egypt the disease also spread to Palestine, Lebanon, Syria, Transjordan and Iraq, and to each of these countries vaccine was sent from Onderstepoort. Thousands of horses and mules were also immunized in South Africa before being despatched, for military purposes, to India ;

and, more recently, many more are being immunized on behalf of UNRRA before despatch to their various destinations in Europe.

Altogether approximately 300,000 doses of vaccine were used in this campaign. The preparation of this large amount, which was additional to the very considerable local requirements in South Africa and neighbouring territories, imposed a great strain on the officers at Onderstepoort responsible for this work. It may be mentioned that in the last two years more than a quarter of a million white mice were bred at Onderstepoort and used for the preparation of this vaccine.

The timely assistance which we were able to render in this instance was certainly of great benefit to the countries concerned and to the armies operating in the Middle East.

We have also supplied the attenuated strains of virus to the veterinary authorities in Egypt (and in Turkey) with the necessary detailed instructions, and they are now in a position to prepare their own vaccine.

BLUETONGUE OF SHEEP

'Bluetongue' or catarrhal fever of sheep may be regarded as a companion disease to horsesickness. Their geographical distribution, seasonal occurrence and mode of transmission are very similar. Recent work has added much to our knowledge of these diseases. It was found, for instance, that the virus particles of bluetongue have an average size of approximately 100 μ, whereas those of horsesickness are about 50 μ in size. Both diseases are transmitted by minute midges belonging to the genus *Culicoides*. In both a number of immunologically different strains of virus has been demonstrated. At least six or seven such strains have been identified in bluetongue.

This plurality of virus strains is a very important factor in the preparation of a vaccine against this disease. Forty years ago Theiler was able to attenuate a strain of bluetongue virus by simple passage through sheep, and the blood of sheep infected with this mild strain was issued as a vaccine. This same vaccine, with minor modifications, has been used ever since. In the forty years which have elapsed some sixty million doses have been issued and have without doubt been instrumental in saving the lives of millions of sheep.

But this vaccine has not been entirely satisfactory. The chief complaint was that in some cases it failed to protect against the virulent disease. And no wonder, since, as we know now, there are other strains of virus against which the single-strain-vaccine would not protect. It is hoped that this difficulty will be overcome by the work now in progress.

Bluetongue virus is being cultivated on incubated eggs. Attenuation is attained after about fifty passages. It has been found that the temperature at which the eggs are kept is of paramount importance. The optimum temperature may vary for different strains. An increase in the temperature of the incubator of 1½ degrees Centigrade may result in a tenfold reduction in the virus content of the embryo.

Large-scale tests are now being conducted in the field with the egg culture vaccine. It will probably be possible to incorporate more than one attenuated strain of virus in the vaccine and so overcome one of the greatest obstacles in the control of this very serious disease.

HEARTWATER OF CATTLE AND SHEEP

This disease, which is caused by a *Rickettsia* (*R. ruminantium*), is to-day probably the most serious problem cattle farmers have to contend with in the low-veld areas of South Africa. It is all the more serious since no effective method of fighting the disease is known. It forms a serious and almost insuperable obstacle against cattle improvement and successful cattle farming generally in the areas where it is enzootic.

At present the only advice that can be given to farmers is to dip their cattle regularly and so try to eradicate the tick (*Amblyomma hebraeum*) which transmits heartwater. But this tick is one of the most difficult to eradicate, although many farmers have proved that it can be done. Perhaps the new insecticides to which we have referred will facilitate this process.

In the meantime other avenues must be explored in an attempt to control the disease and minimize the losses which it now inflicts. Several important facts have been established in connexion with heartwater. In the first place it has been found that the disease usually takes a mild course in very young calves. Secondly it was found that Uleron exerts a very marked influence on the course of the disease ; in fact, it may almost be regarded as a ' specific.' These two facts were used in working out a practical method of immunizing calves. Within the first fortnight or three weeks of their lives the calves are injected intravenously with *fresh* virulent heartwater blood. Usually they react mildly (by virtue of their age) ; but to make doubly sure, they receive an injection of Uleron a week after the infection (and irrespective of the reaction they may show). The method has been adopted as a routine procedure on some farms with excellent results.

This method would undoubtedly be applied generally, if only fresh heartwater virus could be made available. But that is the trouble ! The heartwater virus does not keep for more than a limited number of hours. Our next object therefore is to find a method of preserving heartwater virus.

It was hoped at one time that a culture method might offer a solution, but the rickettsias of heartwater, unlike other *Rickettsia* species, do not grow readily in tissue cultures (e.g. incubated eggs). Our success so far has been only moderate. Nor is heartwater easily transmissible to other animals. The only animal, other than the natural ruminant hosts (cattle, sheep, goats) and perhaps a few antelopes, to which the disease has been transmitted in the laboratory, has been the ferret ; but this has not been of great practical assistance. More research is necessary to find a solution to the problem of immunization which would be of inestimable value to South Africa.

LUMPY SKIN DISEASE OF CATTLE

When this disease first appeared on the western border of the Transvaal about eighteen months ago practically nothing was known about it. A few brief references, under various headings, had been made to an unknown disease in neighbouring territories, but in the scientific literature practically nothing had appeared. Here then we were dealing with a disease new to science.

It has since been ascertained that the disease was first observed in

Northern Rhodesia in 1929, and in Bechuanaland Protectorate in 1943. Apparently it entered the Union from Bechuanaland in December 1944.

During the eighteen months since its first appearance in the Union of South Africa it has spread over the greater part of the Transvaal and Orange Free State and the northern part of Natal—an area more than double the size of Great Britain. Its mode of spread is not yet known, but there is reason to believe that flying insects play a part in the transmission.

Very briefly it may be mentioned that the disease, as its name implies, primarily affects the skin, causing peculiar lumps in or under the skin. Lesions may also appear in the mouth, nostrils, pharynx, larynx, trachea, as well as in some of the internal organs, including the muscles. Swellings of the limbs or other parts of the body are frequently seen. An interesting feature of the histological picture of the lumps is the presence of peculiar inclusion bodies in the histiocytes and epithelial cells.

No bacteria or protozoa have been found and it is assumed at present that the disease is caused by a virus. This ' virus ' is present in the lumps and swellings and also in the blood in the very early stage of the disease.

The mortality from Lumpy Skin Disease is low, probably on an average below 5 per cent, although individual farmers have suffered a much higher mortality, especially in well-bred stock. But the indirect losses may be very considerable. Hides are affected and may be seriously damaged ; the milk supply may be greatly reduced ; secondary infections may cause further damage ; in some cases sterility is said to have ensued.

Investigations have been undertaken to determine the degree and duration of immunity after recovery from the disease. It is too early to say with certainty how long the immunity lasts, but there seems to be reason to expect that it will be of sufficient duration to aim at some method of immunization. What that method is likely to consist of or whether such a process will be possible at all, we cannot yet say.

This disease has been mentioned here as the final example of our outstanding veterinary problems. Its very newness and the many unknown factors in connexion with it render it one of our formidable problems of the immediate future.

Other ' outstanding problems ' could be added to this list, for instance the host of poisonous plants we have in South Africa ; but the examples quoted may be sufficient to illustrate the type of problem with which we have to deal. The solution of all these problems is dependent on another vital problem, namely the shortage of staff and facilities. The war has made this problem acute and it is hoped that the deliberations of this conference will assist in finding a satisfactory solution for this most pressing of all our problems.

PROBLEMS IN AGRICULTURAL SCIENCE IN AUSTRALIA

By Dr H. C. TRUMBLE, M.Agr.Sc., D.Sc.

GENERAL

AUSTRALIA covers three million square miles between the parallels of 10° S and 44° S, approximating in size to the United States, but equipped with inferior material resources compared with that country. Maximum development of agriculture within the limits imposed by climate and soil would probably enable the existing population of 7¼ million to be trebled without impairing current living standards.

The continent is made up of 40 per cent desert, 32 per cent steppe, 15 per cent temperate categories and 13 per cent tropical and sub-tropical savannah woodland with a little rain-forest. In New Guinea, which slightly exceeds one tenth the area of Australia and lies between 11° S and the equator, the conditions are essentially tropical.

The temperate region, to which European and North American types of settlement have proved most satisfactorily adapted, may be further sub-divided into 7 per cent summer-rainfall bordering on the sub-tropical, 5 per cent winter-rainfall or Mediterranean and 3 per cent marine temperate, again expressed as fractions of the continent. Climatic counterparts of these are to be found in India, south-east Asia, South Africa, South America, the south-eastern and western United States, Mediterranean and western Europe, and New Zealand. The climates of Russia, the northern United States and Canada, apart from very small areas, are not paralleled in Australia.

While the above can be accepted in broad terms, much detail requires to be learnt concerning the natural vegetation of the undeveloped areas and the rural complex that has accrued under settlement, in their ecological relationships with climate and soil.

There is need for investigation of the basic resources of effective moisture, temperature and light as specific determinants of the biological activities governing nutrition and the derivation of agricultural products from the soil. The principal soil types have been described and their occurrence mapped from generalized and detailed surveys; but more information is needed concerning soil-plant relationships, with particular emphasis on the modifying effects of climatic variation. Land-use surveys, if conducted along the accepted scientific lines of ecological and statistical principle, could be utilized to assimilate and integrate the results of human experience in occupied regions; detailed agronomic work following climatic, soil and biological surveys of both the unsettled and settled areas would provide insurance against the kinds of calamitous mistakes that have frequently followed trial and error in the past.

METHODS OF APPROACH

Certain methods have now been developed, others are in the process of being examined while further investigation of the following is desirable.

(i) The integration of climatic measures of the key factors, moisture, temperature and light on a basis of time, with reference to the frequency with which particular combinations that could be referred to as ' seasonal types ' occur. This would not only enable local problems to be more accurately orientated but afford a sounder basis for comparisons with the climates of other countries.

(ii) Aerial surveys, both oblique for ecological reconnaissance, and vertical for the detailed mapping of vegetation and soil.

(iii) The analysis in the field of soil-plant relationships, with a view to an improved understanding of the differences revealed by survey.

(iv) The survey in the field, and subsequent inventory and analysis of human experiences.

(v) Methods of soil examination ; cation exchange and the spectrochemical analysis of soils and soil products would repay intensive study.

(vi) The biological assay of soil fertility and the specific factors concerned in the productive capacity of soils.

(vii) Exploratory investigations of limiting factors in soils and their possible modification by artificial means.

(viii) Agronomic investigation of the main avenues by which practical improvement in the efficiency of production can be secured.

(ix) The assessment of the commercial value of improved practical techniques.

(x) The application of economic analysis to the factual data emerging from the above.

There is a general need to discard the older empiricisms of agricultural inquiry and to pursue in scientific depth the problems of greatest practical importance, constantly bearing in mind their relation to the agricultural whole.

SCIENTIFIC PROBLEMS

(i) Vegetation

Analysis of the native vegetation frequently provides a useful indication of latent agricultural resources, deficiencies and potentialities. There is room for a series of monographs on Empire vegetation, along the lines, e.g., of Adamson's Vegetation of South Africa. Much Australian vegetation of negligible commercial value is likely to be eliminated in the future as a prelude to further agricultural settlement ; it should be studied and accurately mapped before clearing has become too general.

(ii) Climate

The moisture factor has been satisfactorily expressed under the conditions of southern Australia in terms of the monthly R/E ratio, together with the amount of rain received where this ratio is above a certain critical value. The methods followed in the south need to be tested in principle for the tropical and sub-tropical conditions of the north and modifications or alternative measures, if necessary, developed.

Probabilities based on frequency of occurrence of periods sufficient or deficient in moisture require to be determined to afford a basis for the prediction of climatic risks, which in Australia are largely associated with the moisture factor. Light quality and intensity on a duration basis, and the relationships of light and temperature to photosynthetic activity and to the dynamics of micronutrient absorption and transfer (e.g. zinc), with particular reference to legumes, are in need of close physiological study. Herbage legumes appear generally to fail in tropical and near-tropical climates, not only in Australia, but also in other countries. The reasons for this failure require investigation.

(iii) Soils

There is a major problem of soil erosion due both to water and to wind where agricultural and pastoral activities of the exploitative type have been practised. Its incidence is more widespread than has been popularly supposed, but the scientific knowledge on which constructive remedial measures can be based is available in Australia ; the problem is essentially one of national leadership in the direction of encouraging landholders to rectify their own position, with organization for instruction, the conditional provision of appropriate finance and legal means of enforcement where necessary.

The water relations of the main soil types are in need of investigation. There appears to be evidence of widespread micronutrient deficiency in addition to the recognized paucity of available phosphate, nitrogen and in some areas potash, over certain portions of southern and eastern Australia. The relations of these to the geochemistry of the basic rock formations, climate and past land history need to be worked out, together with means of overcoming deficiencies that limit production or nutrition.

The factors governing the supply of available plant-foods according to the crop grown, climatic influences, the physical and chemical features of the soil and management are little understood.

The microbiological activities of the soil as determined by physical, chemical and biochemical changes, and the relation of microbiological developments to modifications of soil fertility, have scarcely been examined in Australia and provide what is likely to be a fruitful field for investigation.

There is the whole question of organic as compared with mineral fertilizers and the relation of micronutrient impurities in each to their practical value. The rôle of organic acids in soils requires to be determined.

The relation of the inter-play of physical and biological factors to the absorption and excretion of nutrients and inhibitory substances in soils is another matter that would repay detailed investigation.

(iv) Elimination of arboreal vegetation

The initial clearing of dense timber in the areas of highest and most assured rainfall presents an acute problem as the timber itself is frequently of limited value compared with the high costs of labour required to permit agricultural machinery to operate. Here possibly lies one field in which tests of atomic energy, as a means of destruction prerequisite to constructive development, might be justified.

In some of the higher rainfall areas, and especially over extensive areas

of cattle country in Queensland, regeneration of endemic species of *Eucalyptus* and *Angophora*, both from root suckers and seedlings, presents a serious and little-understood problem. The recently commercialized growth-inhibiting substances, such as derivatives of phenoxyacetic acid, might repay investigation in this field.

(v) Pastures

This is the subject of a separate contribution by Dr J. Griffiths Davies, the main points of which are incorporated herein (sections iv, v and viii).

The problems concern (a) pastoral lands supporting livestock in fair concentration according to the physical resources available, but capable in many cases of being substantially improved in productivity, (b) areas under climax woodland or scrub with sufficient effective rainfall to justify development through pasture establishment, and (c) irrigable lands.

(a) *Pastoral lands already supporting livestock*

The improved pastures devoted to dairying in favoured situations within the coastal belt of south-eastern and eastern Australia appear to offer no special problems apart from those associated with improved methods of rotational farming and fodder conservation.

Soils derived from calcareous, lateritic, quartzitic and granitic parent material occur extensively in the higher rainfall areas of Australia. Podsolization in varying degrees is common. Animal production is not usually so successful on these as on more highly mineralized soils ; and herbage legumes frequently fail to develop, despite liberal top-dressing with soluble phosphate. Deficiencies of both major and minor nutrient elements probably occur fairly widely. These may frequently be of a complex nature, involving the interaction of several : e.g. phosphorous, nitrogen, copper, zinc and molybdenum have been shown to be lacking in some soils of the Mount Lofty ranges in South Australia. In parts of Western Australia, vigorous stands of subterranean clover have developed, but the normal succession to ultimate grass dominance appears to be inhibited and the pastures are not associated with efficient livestock production. These soils, of which there are numerous sub-types, afford abundant scope for the investigation of the mineral nutrition of herbage plants and the factors governing the accumulation and exhaustion of available minerals in the soil.

The semi-arid and arid pastoral lands maintain, for the most part, sheep in the south and cattle in the north. A better knowledge of the andemic species of *Atriplex*, *Kochia*, *Danthonia*, *Stipa*, *Eragrostis*, *Astrebla*, etc., end other genera is required, with emphasis on the regeneration of areas denuded by exploitative stocking and the development of grazing methods which permit the vegetative cover to be conserved as well as profitably utilized.

The pastoral areas of northern Australia are as yet little understood ; and work of an exploratory nature, including surveys of the type already indicated, is needed. The herbage legume problem is important.

In the main cropping region of eastern and southern Australia, deterioration under wheat-growing on the wheat-fallow system in particular has

emphasized the value of longer rotations incorporating lucerne and other forms of temporary ley.

(b) *Areas under climax woodland or scrub but capable of development*

Fire is a potent agency in clearing, and effective mechanical aids to rolling and ploughing have been developed. In South Australia, the conservation of edaphic resources by burning and deep ploughing for fallow, with the incorporation of the maximum ash available from the burn, and the elimination of both crops and rye-grass from the initial seeding lead to a vigorous early development of clover, which is the first essential of successful pasture establishment on naturally deficient soils. Much land will shortly be cleared and sown along these lines for post-war settlement, but the mineral nutrition of the subsequent pastures requires further investigation.

A proportion of the temperate region with the most favourable conditions of rainfall is still occupied by native woodland, scrub or heath and the successful conversion of these areas to pastoral and agricultural activity would be one major factor in the future expansion of primary industry in Australia. Practical development had commenced prior to 1939 but was arrested by the war. Fortunately, researches on some soils have proceeded sufficiently to provide for present needs ; but an expansion of the investigational work is essential to safeguard the future.

(c) *Irrigable lands*

Newly opened irrigable land along the river valleys of southern New South Wales is of heavy texture and low organic status with a high content of dispersible clay, leading to poor infiltration. Investigations are planned to test the influence of pre-cropping with winter cereals and rice as conditioning agents and to determine the cultural treatments, seeds mixtures, fertilizer applications and irrigation practices most likely to ensure the successful establishment and maintenance of pastures on these relatively intractable soils. Somewhat similar types of soil, but characterized in addition by a fairly high content of soluble salts (0·1—1·0 per cent), extend along the Murray river into South Australia. Low-lift pumping is economic if requisite production is assured.

The Ord river developmental project in the Kimberley district of north Western Australia also concerns irrigable soils of heavy texture with a low infiltration rate.

Owing to the importance of the pastoral industries to Australia and the dependence of future soil-building on pasture development, the problems outlined in this section are regarded as having a special significance in the future welfare of the country. There is abundant scope for overseas exploration, selection and breeding to secure improved pasture types ; a wealth of material awaits investigation.

(vi) Field crops

Most work in the past has been devoted to wheat ; in more recent years increasing attention has been paid to sugar-cane, oats, barley, maize, flax, potatoes, rice, peas, tobacco and cotton, with some reference to soya

beans. During the war, opium poppy, pyrethrum and the guayule rubber plant were successfully cultivated.

Work has been carried out on the derivation of the alkaloids hyoscine and atropine from native *Duboisia spp.*, with attention to the cultivation of selected types. Oil-bearing plants such as linseed and safflower have also been investigated.

There is general need for diversification of cropping, but this may depend on the comprehensive introduction and selection of many new types, their investigation by modern agronomic methods under varying habitat conditions, and the inauguration, where justified, of practical breeding programmes. Unfortunately, much earlier work on possible new crops was empirical, without good scientific foundation, or synthetically academic and unrelated to practical needs. The physiological and ecological factors governing the smoking quality of Australian-grown tobacco are still not satisfactorily known, and much agronomic work remains to be conducted with this and other field-crops.

The practical rôle of new crops needs to be considered in relation to human efficiency including the scope for mechanization and the factors of economics concerned. The trends that accrue in New Guinea and adjoining areas will depend on future policy regarding native populations.

(vii) Horticultural crops

The nutritional and water requirements of standard fruit and vegetable crops require to be determined and the ecological relationships of different varieties to be defined. There is room for investigating the role of plant growth substances in modifying the development and cropping habits of fruit trees ; physiological diseases of nutritional origin, determined by particular conditions of soil and climate, and sometimes related to certain disorders following storage require examination.

Exploration, selection and breeding to develop varieties and rootstocks suited to specific environments have been little followed in Australia. In some cases, e.g. the potato, disease-resistant genes are available, but agronomic work is needed to define the ecological relationships of standard varieties.

(viii) Forest crops

The relative value of developing poor lands receiving liberal rainfall under softwood forest or pasture is not known. The climatic and nutritional relationships of forest types require investigation, there is scope for considerable afforestation on farms in Australia, either by natural regeneration or artificial plantings on selected portions of the holdings.

(ix) Control of weeds

The investigation of weeds now tends to be based on their ecological relationships, with emphasis on competitive influences ; work of this kind needs to be intensified.

The following weeds are among the more serious and have proved difficult to eradicate :

Bassia Birchii F. Muell., *Chondrilla juncea* L., *Convolvulus arvensis* L., *Cyperus rotundus* L., *Homeria collina* (Thunb.) Vent. and *H. miniata* Sweet, *Lepidium*

Draba L., *Pteridium aquilinum* L. Kuhn, *Rubus fruticosus* L., *Salvia reflexa* Hornem., *Xanthium spinosum* L. and *X. pungens* Wallr.

Extensive tests with arsenates and chlorates have been consistently unsuccessful ; the newer synthetic hormone-like derivatives of the chloroxone and methoxone type have given encouraging results in preliminary trials and merit detailed investigation.

(x) Physiological investigations

Physiological work could be undertaken in close association with investigations along ecological or agronomic lines, to enable sound scientific interpretations of the biological phenomena observed in the field to be developed. The place of the micronutrients copper, zinc and molybdenum within the enzyme systems of herbage legumes and grasses alone provides a comprehensive and important subject for investigation.

(xi) Genetics

The introduction of genes for disease resistance has been accomplished in the case of wheat (stem rust, bunt, flag smut, mildew), barley (covered smut, mildew), flax (rust), tomatoes (leaf mould), potatoes (virus x, leaf roll), and the back-cross method of incorporating disease resistance into standard varieties has been adopted with practical success. We are still far from understanding the physiological or biochemical nature of disease resistance.

Studies of varieties and inheritance in the fungi, as for example in *Neurospora*, *Venturia* and the yeasts would be helpful under Australian conditions.

(xii) Plant diseases

The general incidence of disease in Australia has not so far proved considerable. Physiological disturbances commonly referred to under this category but attributable to deficiencies of available minerals are becoming more clearly defined. Serious virus diseases of stone fruits such as occur in the United States apparently have not occurred in Australia.

Emphasis has been given to the significance of factors associated with an improved level of available plant-foods in overcoming take-all and root rots of wheat (*Ophiobolus*, *Rhizoctonia*, *Fusarium*, etc.). The losses due to these diseases are apparently only slight in comparison with those sustained in the pioneering phases.

The control of disease is most effectively secured by the incorporation of disease-resistant genes in standard crop varieties ; although much work has been carried out on the spotted wilt virus of tomatoes, tobacco and related plants, the varieties of tomato grown in Australia are still susceptible. A genetical approach to the problem, based on the wealth of material available in the genus *Nicotiana*, might be fruitful.

ACKNOWLEDGMENTS

In the short time available it has not been possible to consult several colleagues whose experiences and opinions would have improved this somewhat sketchy account ; and to them apologies are submitted. In

addition to the contribution by Dr Davies, the following have given freely of their ideas : Prof. S. M. Wadham, Dr N. S. Noble, Dr B. T. Dickson, Mr C. G. Stephens, Prof. E. Ashby, Dr J. Bald, Dr C. Barnard, Mr W. Hartley, Mr D. B. Adam, Mr A. G. Strickland, Dr H. C. Forster, Mr G. Leeper, Mr A. T. Pugsley and Mr C. R. Millikan.

PROBLEMS IN AGRICULTURAL SCIENCE IN AUSTRALIA: FOOD PRESERVATION

By Dr J. R. VICKERY
(Division of Food Preservation, C.S.I.R.)

FRESH FRUIT AND VEGETABLES

THE following outstanding problems cover the field of fresh fruit and vegetable storage and are common to such investigations in all parts of the world.

BIOCHEMICAL AND PHYSIOLOGICAL FACTORS INVOLVED IN RIPENING AND SENESCENCE IN FRUIT

Until we understand the normal metabolism of the cells and organs, we shall be unable to determine the best techniques for storage of fresh fruit and vegetables. So far work in this country has followed the same lines as most overseas work. A start has been made with the study of cellular metabolism and it is proposed to extend investigations on this problem.

CAUSES OF NON-PARASITIC DISORDERS IN COLD-STORED FRUIT AND VEGETABLES

It is well known that maturity at picking is important in determining the liability to storage disorders such as jonathan spot, superficial scald and breakdown in apples, scald and rind-pitting in oranges, and abnormal ripening after removal in pears and soft fruits. Considerable information has been obtained about the effect of various external factors such as storage temperatures, storage atmospheres, special wraps and skin coatings, on the incidence of such disorders. Much work must yet be done before the causes of these disorders are thoroughly understood.

THE MECHANISMS CONTROLLING THE DEVELOPMENT AND GROWTH OF FUNGAL PATHOGENS IN STORED FRUIT AND VEGETABLES

As a result of some success in reducing the incidence of non-parasitic disorders, the relative importance of storage-rots is increasing. This raises the difficult question of host-parasite relations. It is hoped that investigations on this problem will be commenced soon.

THE MEANING OF THE TERM 'QUALITY' IN FRUIT AND VEGETABLES

Definitions are required for 'quality' in fruit and vegetables which are to be consumed fresh, after storage or after processing. The large number of variables, e.g. flavour, colour, texture, vitamin content, calorific value, etc., on which quality for any of these purposes depends,

makes difficult the accurate assessing of the value of a particular product. Collaborative work, between food scientists and plant breeders, on the desirable qualities to be developed in new varieties has been commenced and it is hoped that this will be extended further.

Factors influencing desiccation in stored fruit

Evaporation of water from fruit and vegetables, besides causing a loss in weight, often results in a poor and noticeably shrivelled appearance. The effect of external factors such as temperature, humidity and rate of air-flow is fairly well understood, but the surface properties of the foodstuff itself would probably repay investigation. Ashby and Pidgeon, of the Botany School, Sydney University, have found that dipping oranges in alkaline solutions produces a considerable increase in rate of evaporation. This increase is reversible and disappears when the alkali is washed off.

GENERAL CHEMICAL PROBLEMS

The flavouring constituents of fruit, vegetables, meat, fish and eggs

During storage of perishable foods, various changes occur, resulting in loss of fresh flavour and finally the development of ' off ' flavours. Volatile esters have been identified in certain fruit, and certain bases in meat products have been regarded as contributing to flavour. Otherwise information is negligible. Deterioration of flavour is now indicated almost entirely by tasting tests but it would be a considerable advance if these could be supplemented by more objective chemical determinations. Knowledge of flavouring constituents might also provide more exact maturity standards in picking fruits for storage and transport.

In this connexion there is evidence that certain volatile constituents of apples are associated with a storage disorder known as superficial scald, and general work on volatile constituents might lead to their identification.

Changes in the proteins of dried foods during storage at temperatures below 40° C.

Marked changes in the solubility of the protein fraction of many dried foods—e.g. dried milk, egg powder—occur during storage at room temperature. These changes are accompanied by the onset of ' off ' flavours, e.g. a ' burnt ' flavour during storage at temperatures above 25° C. As the result of these changes the storage ' life ' of many dried foods is often rather short.

The mechanism of these changes is still obscure and it is hoped shortly to start detailed chemical studies on the problem.

Changes in the proteins of muscle during storage in the frozen state

During freezing and storage in the frozen condition, the proteins of muscle tissue, e.g. of fish, undergo certain irreversible changes leading to marked alteration in the texture of the flesh and to the production of a viscous exudate (drip) after thawing. The usefulness of storage in the

frozen condition as a means of long-term preservation is thereby limited rather seriously.

While a considerable amount of data has been obtained by investigators in several countries, including Australia, the mechanism of these changes has not been adequately defined.

MICROBIOLOGY

Control of bacterial growth on chilled meat

Bacterial growth on the surface tissues is the most important cause of spoilage in meat stored at temperatures above, and slightly below, the freezing point of the muscle (—1° C.).

Apart from the adoption of certain measures to reduce initial bacterial contamination, the only practicable methods now available for retarding the onset of spoilage are the use of carbon dioxide in the storage environment and the reduction of the temperature to about —1° C. As both methods often have certain disadvantages and do not inhibit growth, detailed investigations of the physiology of the main spoilage organisms and the effects of various bacteriostatic agents are urgently needed. Some preliminary investigations have been commenced in Australia.

PHYSICS AND ENGINEERING

Prediction of rates of cooling and rates of evaporation from meat during chilling

It was shown in the course of chilled beef investigations that the rate of cooling and the rate of evaporation from the meat surfaces during chilling both affect the bacterial population on the surfaces and, consequently, the ' life ' of the chilled meat. Loss of weight during chilling is also of direct interest. The problem is oı general interest wherever large quantities of meat have to be cooled rapidly.

It is easy to formulate equations for the cooling of a wet body but it is necessary to use approximation methods for their numerical solution. Suitable methods have been worked out and an arithmetical study, with experimental checks, of the effects on the cooling of plane slabs of wet material of various factors related to the design and operation of cooling-rooms is being carried out. The results will be checked and applied in full-scale cooling rooms as far as possible.

MORNING SUBJECT (b, i)

A SURVEY OF SOME OUTSTANDING PROBLEMS IN MEDICAL SCIENCE. DISCUSSION OF THE PHYSIOLOGICAL AND PSYCHOLOGICAL FACTORS AFFECTING HUMAN LIFE AND WORK UNDER TROPICAL CONDITIONS AND IN INDUSTRY

STEERING GROUP

Chairman—Professor C. H. Best, F.R.S.

Recorder—Dr J. S. Weiner

Dr S. Adler
Dr F. M. Burnet, F.R.S.
Dr E. H. Cluver
Professor C. E. Hercus
Sir Edward Mellanby, F.R.S.
Colonel Sir S. S. Sokhey

REPORT

At this discussion delegates and guests found an opportunity to review some of the valuable scientific work on human efficiency at high environmental temperatures that had been done during the war. The work in this field carried out by the Industrial Health Research Board since the war of 1914–1918 was also considered.

With regard to industry, there was no doubt as to the decline in efficiency noted at high temperatures ; coal miners, for example, had a working efficiency lower by 40 per cent at 86° F. than when working at about 70° F. ; and in a group of badly ventilated tinplate factories the output on the hottest days was about 30 per cent less than in colder weather. Accidents, too, rose as much as 40 per cent when the temperature exceeded 75° F., as was found in munition factories and in mines. As a result of such investigations it was necessary to lay down desirable standards of warmth and comfort. To do this ' warmth-scales ' had to be devised which took account of the combined effect of the factors which made up the thermal environment—the temperature, humidity and rate of movement of the air, and the radiation from the surroundings. The usefulness and limitations of the different scales proposed or in use in this country and the U.S.A. were considered. During the war it was necessary to decide on a scale of warmth for use in His Majesty's ships, particularly for use in the tropics. There was, of course, no time to undertake the elaborate research necessary, but a provisional scale, the scale of ' corrected effective temperature ' by which an allowance could be made for radiation, had appeared in practice to be quite useful.

It was emphasized that much of the available knowledge was capable of direct application to conditions in the tropics. There was need, however, of much more research. A well validated comfort scale for the tropics needed to be established ; improvements in available instruments for measuring radiation and air-movement were desirable. Data on the relation of efficiency to environment, so as to lay down the optimum working day and week and ' comfort scales ' for different industries, should also be obtained. There was much to be done on the building and engineering aspects of this problem. During a recent visit to India one speaker was struck with the obvious unsuitability of many of the factory buildings. The scope of air-conditioning in factories in the tropics required

serious consideration, as many technical questions remained to be solved. The following suggestions were put forward in discussion :

(a) A committee should be appointed to consider tropical building construction with reference to questions of general design, building materials, roof construction, air-conditioning practice and other cooling methods.

(b) A series of authoritative handbooks should be issued on the design and construction of buildings in the tropics on the lines of those published recently in this country by H.M. Stationery Office under the title of Post-War Building Studies.

(c) Consideration should be given for the provision of the necessary facilities for physiological research and for the development and testing of equipment.

An outline of the psychological research carried out at Cambridge for the Royal Navy on the effects of heat on human efficiency was presented. The first problem was whether there was a critical point on the temperature scale above which human performance deteriorated, or whether some forms of activity were affected more than others. A wide variety of real-life human activities had been studied, including tests involving moderate physical activity, high speed semi-automatic work, hard thinking and monotony. It had been discovered in experiments on large numbers of men that an increase in the number of errors occurred in many of these tests above about 85° F. on the ' effective ' temperature scale, and that the number of errors increased rapidly at still higher temperatures. A study of the effect of high temperatures on sleep had also clearly indicated a marked increase in restlessness at high temperatures.

A second problem had been to discover whether a relatively simple bodily measurement, such as a raised body temperature, could be relied on to indicate the likelihood of deterioration in performance. With certain provisos this relation appeared to hold.

These results had been obtained by experiments with young adults, well acclimatized and wearing only ' shorts,' and given brief exposures. It was clearly necessary for these experiments to be extended to tropical conditions of exposure, acclimatization and clothing.

The work carried out by the Climatic Team of the Medical Research Council under Dr E. A. Carmichael had elucidated the relative importance of various environmental and bodily factors on the performance of muscular work. The relative effect of the dry-bulb and wet-bulb temperatures on physiological responses during work had been measured. The late J. S. Haldane's contention that the wet-bulb temperature was of prime importance has been well substantiated. The effect of air movement on men working, lightly or heavily clothed, had shown that present standards underestimated the effects of still air. From these studies the limitations of the widely used American ' effective ' temperature scale could be appreciated. These studies had made it possible to lay down desirable standards for various grades of work in the Services having regard to clothing, acclimatization, training and water supply.

Other practical work during the war had concerned the best fabric (of

those readily available) for tropical service. It had been established that a thin, tightly woven fabric resistant to mosquito bites imposed no greater thermal load than the thicker open-weave mosquito penetrable fabrics in general use. Both in the Navy and in the Army this had led to a change in fabrics for tropical service. Work during the war had also dealt with methods of cooling men in hot situations by special ventilated suits and spot cooling. Such work was of possible use in mining. Clinical research in the field had been carried out into dehydration and salt-deficiency. As a result of the work carried out by Ladell and Waterlow in Persia, a better understanding of the significance and treatment of ' heat exhaustion ' had been obtained.

All this represented the applied aspects of heat physiology. During the war some of the more fundamental aspects had also been studied. The basic physiology of adaptation to high temperature had been pursued in experiments on acclimatization, circulatory adaptation, the activity of sweat glands, the composition of sweat, kidney function and on salt and water metabolism.

An intensification of research on both the applied and fundamental aspects was needed ; the former especially required the validation of results in ' field ' bases in the tropics. The latter needed physiological equipment of a type and scale only available at present in centres in Britain and Australia ; for fundamental research a co-ordinated system of ' base ' and ' field ' laboratories was very desirable. The scale on which research in this subject had been pursued in the British Empire before and during the war was contrasted with that which was possible with the superior resources enjoyed by the Americans. In this field Empire co-operation could be very fruitful. Colonial medical graduates should be encouraged to engage in climatological research both in their home territories and in this country and Australia.

Professor D. H. J. Lee, in a written communication, summarized the work carried out in Australia on tropical habitability. In substance his proposals were similar to those of previous speakers. He called for larger facilities for fundamental work, greater emphasis on field studies, and closer co-ordination within the Empire. He asked also for collaboration with workers engaged in the tropical aspects of animal physiology.

A South African delegate directed attention to the urgent practical problem facing the Rand mines, where underground conditions had in many places reached the critical limit established by the physiological and psychological research described by previous speakers. He felt that further development of some of the war-time research would aid in solving the South African industrial high temperature problem. There was the question of dry versus wet mining to be investigated physiologically, and such questions as acclimatization and selection, which had already received attention on the Rand, needed further study. The relation of the climatic problems to the dust hazard was the outstanding question that faced them in South Africa.

A delegate from Southern Rhodesia pointed out that most of the war work had emphasized humid tropical climates ; there were, however, many problems still unsolved affecting hot dry and desert climates. Clothing in relation to wind and sunlight was one such problem—should

it be the minimum, as our troops had adopted, or was there anything in the traditional Arab type of costume? The correct amount of salt was still not a settled question. There were also other questions of diet and housing.

An Indian medical delegate agreed as to the general unsuitability of factory buildings in the tropics, especially in India. There were, however, traditional building methods and materials which were undoubtedly superior to the corrugated iron and ill-ventilated structures of the present day. He would welcome building research in India and hoped that traditional ideas would be carefully assessed. Further physiological studies into the state of adaptation or acclimatization of native peoples as compared with that of new arrivals would be worth while.

Experience in West Africa had shown the value of relatively simple methods of improving 'habitability,' such as thatched roofs instead of corrugated iron, whitewashed walls, and even a 'cold water bottle' was a help. The need for research into building methods and air conditioning was again emphasized.

Professor D. Brunt, commenting on the empirical comfort scales in general use, pointed out that a single general formula could be established to relate the purely physical factors of heat flow and heat production to man's body temperature and thermal equilibrium. Many of the results in the literature supported the equation he put forward, though more work was needed to extend the applicability of the various physical constants.

General statement

The Conference surveyed certain of the results obtained during the war in the laboratories of the Medical Research Council at Cambridge and London, and in the Department of Physiology, University of Queensland. It was agreed that much of this work had a general application to many countries of the Empire. It was agreed further that facilities for developing this work, both in laboratories in the 'field' and in suitably equipped centres in the United Kingdom and Dominions were desirable.

Recommendations

1. Physiological and psychological research carried out under artificial conditions for war-time purposes needs to be extended to actual conditions in the tropics and to industries in which high temperatures are encountered. This would require the establishment at suitable centres (for example, in Africa and in the Far East) of well-equipped laboratories. These should work in close contact with similar laboratories in the United Kingdom and Australia, in which the more basic research should be carried out.
2. Research on output in industry in the tropics needs to be carried out as data are practically non-existent. Investigation is required also into the habitability problems of clothing, housing and transport.
3. Attention is directed to the need for improvement of instruments for the study of climatic factors.

4. An authoritative guide on standards for building (domestic and industrial) in the tropics on the lines of the reports of the Building Research Station of D.S.I.R. is desirable.

5. War-time standards of ventilating practice in the Services need to be reviewed in relation to civilian and industrial conditions in the tropics. A revision of existing scales of warmth and comfort is urgently required.

6. There is a definite need for co-ordination within the Commonwealth. This should take the form of exchange both of workers and of information. It is suggested that a co-ordinating *Empire Committee on Human Climatology* should be set up. This would include workers in physiology, psychology, industrial hygiene, the related aspects of nutrition and also representatives from the allied field of tropical animal physiology.

7. It is strongly recommended that provision be made for a number of research fellowships for *colonial* medical graduates, to enable them to carry out research in climatological laboratories.

8. The participation, by the Commonwealth countries concerned, in a co-operative study of air conditioning and the consequent engineering developments, is recommended.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr T. Bedford

Introduction. Man's efficiency and general well-being are greatly influenced by the warmth of the environment in which he lives and works. Prolonged exposure to very high temperatures may lead to heat stroke or heat collapse, but even at temperatures well below those at which such disturbances occur there is a substantial loss of working efficiency and increased liability to accidents, and of course there is serious discomfort.

Various researches carried out by the Industrial Health Research Board in Great Britain have shown the decline of working efficiency with rising temperature. Observations made on coal miners showed that men working in mines where the temperature was 86° F. had a working efficiency 40 per cent less than that of men working at a temperature of about 70° F.

In other hot and heavy industries the influence of temperature on production is clearly shown by the seasonal variations on output. In the steel, tinplate and glass bottle industries investigations have shown that output is greater in the winter months when the factories are cool than in the summer when they become hot. In a group of tinplate factories the rate of production in the hottest month of the year was 10 per cent less than that in the coldest. In the worst ventilated factory, where seasonal temperature variations were most felt, the output on the hottest days was about 30 per cent less than in the coldest weather.

Even in the lighter work of weaving textile fabrics excessive temperatures and humidities exert a clearly demonstrable effect in reducing output, although high temperatures and high humidities are the physical conditions most favourable to the weaving processes. In humid factories, when the temperature was above 75° F., the adverse physiological effects on the weavers more than counterbalanced the favourable physical conditions for weaving and output declined.

Excessively warm environments influence the risk of accidents. In munition factories during the war of 1914–1918, it was found that accidents were at a minimum when the factory temperature was between 65° F. and 70° F. When the temperature rose above 75° F. the accident rate increased by 40 per cent.

Accidents amongst miners are also influenced by temperatures at which work is done. In hot mines the accident frequency rate is substantially higher than in cooler ones. Temperature also affects the distribution of accidents in the various age groups. Other studies of accidents have shown that age and experience tend to diminish the accident risk, while on the other hand fatigue increases it. In coal mines it was shown that men working at temperatures below 70° F. had the lowest accident rates, and

those working at temperatures above 80° F. had the highest. In the coolest mines the accident rates declined with increasing age, reaching a minimum frequency in the 40 to 49 group, and then increasing slightly in the older men. In the two warmer groups of mines the minimum frequency was reached at ages 30 to 39, but whereas in the intermediate group the men aged 40 to 49 had only slightly more accidents than those aged 30 to 39, in the hottest mines there was a sharp increase in the accident frequency in the 30 to 39 to the 40 to 49 group. Hard work is more trying when it is done at high temperatures, and the older men are more easily fatigued by work under such conditions.

These results have been obtained by British workers accustomed to the climate of Great Britain. The temperatures at which like effects will occur in persons of other races accustomed to tropical climates may be somewhat different, but there can be no doubt that excessively high temperatures will militate against their well-being.

Measurement of warmth. The factors which make up the thermal environments are four in number : the temperature, humidity, and rate of movement of the air, and the radiation from the surroundings. In the study of the physiological effects of warmth all these factors must be taken into account. Air temperature and humidity are conveniently measured by means of the ventilated hygrometer. Air velocities, even low velocities which occur in closed rooms, are readily measured by means of the kata thermometer, and if the bulb of that instrument is silvered radiation errors are avoided. The mean intensity of radiation at an observation point can be estimated with satisfactory accuracy by the use of a globe thermometer.

It is clearly desirable that we should have some yardstick by which the combined effects of all these factors can be expressed in a single index. On the basis of observations made during the winter months on factory workers in this country, I put forward a scale of what was called *equivalent warmth.* The scale makes due allowance of each of the four factors, but it does not yet extend to temperatures higher than about 75° F., and is therefore not applicable to tropical conditions.

Over twenty years ago American workers constructed scales of *effective temperature* by which allowance is made for air temperature, humidity and air movement. Unfortunately, no allowance is made for radiant heat, and in some environments, such as machine spaces in ships and lightly constructed buildings in the tropics, this is a serious drawback.

During the war it was necessary to decide on a measure of warmth for use in His Majesty's ships. The scale of warmth was urgently required, and there was not time to undertake the prolonged research which would be necessary to establish a new scale. It was therefore decided to use effective temperature with an adjustment to allow for radiant heat. This allowance is made by substituting the temperature of the globe thermometer for the air temperature in the dry bulb temperature scale of the effective temperature chart. Calculations based on the few pertinent physiological data which are available suggest that the modification is a reasonable one. The scale of *corrected effective temperature*, as it has been called, has been provisionally adopted for use in the Royal Navy. It is described in Medical Research Council War Memorandum No. 17, and should be of some assistance to those concerned with temperature conditions in the tropics.

Measuring Instruments. The globe thermometer has proved itself a valuable instrument for the estimation of the mean intensity of radiation. It has one drawback which is sometimes serious, namely, it has a slow response to changes of environment due to its considerable heat capacity. It takes about twenty minutes for the globe to reach equilibrium in a fresh environment. An instrument which would serve the same purpose but respond much more quickly would be of more value.

In studies of the thermal environment the kata thermometer has been widely used for the measurement of air velocities. It is simple and can be used by those who are not accustomed to handling elaborate apparatus. A disadvantage is that it takes some minutes for each observation. For many purposes it would be of value to have an instrument with a quicker response. One of my colleagues is experimenting with a supersonic anemometer which, it is expected, will give quick and accurate results even at very low velocities, and it is hoped that it will also indicate the direction of air flow.

Assessment of warmth. A major problem on which research is urgently needed is the construction of a revised scale of warmth. I have mentioned the scale of corrected effective temperature which has been used in the Royal Navy. Apart from other considerations it is necessary that the validity of the radiation correction should be checked. There are other reasons, however, why further work is needed. Within the past year or two it has been found by research workers in Great Britain and America that in environments so hot that they can only be tolerated for relatively short periods, for example when the wet bulb temperature exceeds 90° F., the effective temperature scale makes an excessive allowance for the dry bulb temperature of the air. In such extreme conditions the wet bulb by itself appears to be a better index of warmth than effective temperature. Yet recent information from America points to the conclusion that at rather lower, yet safer, temperatures which represent the limiting conditions that can be tolerated for prolonged work, the effective temperature is a better index than merely the wet bulb temperature. Further, it appears that at high temperatures the effective temperature scale does not make enough allowance for the refreshing effects of relatively light air currents. Effective temperature has been of great value to physiologists and to air-conditioning engineers, but it clearly needs to be checked, and radiation must be introduced as another variable. A revised scale of warmth is needed not only by physiologists, but also by engineers who are concerned with air-conditioning problems, and by architects who are designing buildings for erection in hot climates.

Other studies of the effects of high temperatures. Much of the war-time research on high temperatures has been concerned with the maximum temperatures at which men can perform specified tasks for relatively short periods. Valuable as this work has been, other information is needed for application to the industrial problems of peace. We want to know what are maximum temperatures to which men performing work of varying degrees of severity can reasonably be exposed day after day, and year after year. It is necessary to know these limits in terms of a scale of warmth which takes into account all the thermal factors. It is important, for instance, to know how far air movement can mitigate the effects of high temperature,

and when increased air movement may be undesirable. In many circumstances one wants to know how much importance should be attached to the screening or insulation of radiating surfaces.

If hard physical work must be done in great heat, what is the maximum period for which that work should be done under such conditions, and what is the best way of arranging work spells ? It seems quite probable that in the conditions which prevail in some industries in the tropics a 48-hour week will be too long for efficient and healthy employment.

Other questions relate to the cooling of buildings by air conditioning. It is of considerable practical importance to know whether, in hot climates, and especially in hot and humid climates, cooling by air-conditioning should be achieved by a reduction of the air temperature without the removal of much water vapour from the air, or whether the air should be dried and only cooled to a small extent. There is need for information as to the maximum amount of cooling which is desirable under various climatic conditions and in various types of building.

It is my hope that work on these problems may be carried out in Great Britain, but for the purpose of India, for instance, much of the work needs to be done with Indians living under Indian conditions as the experimental subjects, for differences in physique, nutrition, habits of life, and acclimatization may all influence the results.

To construct the new scale of warmth and answer these other questions will need arduous work over a long period and it will involve considerable expense. It will need the provision of costly experimental chambers in which each of the individual thermal factors can be controlled over a wide range.

There is, by the way, yet another need for such tropical research facilities. In this country, equipment is constructed for the transport of perishable products in the tropics, and there are at present no satisfactory facilities for testing this equipment under tropical conditions when it has been made.

Tropical buildings. Recently H.M. Stationery Office has published a series of authoritative handbooks under the general title of Post-War Building Studies. These deal with all aspects of the construction and equipment of buildings. It seems to me that there is good scope for an authoritative statement on the design and construction of buildings in the tropics. I have recently returned from a tour in India where I visited a large number of factories. While many residences and public buildings in India seem to be admirably suited to the climate, I was impressed by the unsuitability of the great majority of the factory buildings which I saw. Most of the factories were roofed with a single sheet of corrugated iron ; such a roof affords little protection from solar radiation. Commonly the air temperature in a building so roofed is 10° F. higher than that of a building with an insulated roof, and in addition the radiation from the thin roof imposes a further strain on the occupants. A corrugated iron roof may have a low first cost, but in the long run it cannot be economical.

A Committee appointed to consider tropical building construction might well include persons with expert knowledge of factory conditions, industrial hygiene, air-conditioning and illumination, as well as specialists in other branches of building construction and design. Consideration should be given to the general structure and planning of buildings and

especially to roof construction from the standpoints of protection from solar radiation and of natural lighting. It should further be considered how far air-conditioning is desirable in different types of buildings, and how far it is practicable. Where air-conditioning is desirable are changes in the design of building necessary? Is it desirable, for instance, in air-conditioned buildings, to reduce the height of the roof or ceiling below that which is now customary?

A further question which applies to non-industrial buildings is the possibility of using radiant cooling methods.

The report of a Committee such as I have mentioned, given wide publicity, would be of very great value.

Empire co-operation. As researches on these tropical questions are likely to be made in various parts of the Empire, there is a very clear need for consultation and perhaps collaboration between the various teams of workers. There is need for the early exchange of information through official channels, and probably even more important will be the close but informal contacts between scientific workers engaged on similar types of research.

Dr D. M. Blair

I would like to make a plea for more study of the effect of high temperature under natural climatic conditions where the humidity of the atmosphere is low. A great deal of work has been done especially in the study of work conditions in industry where high temperatures *and* high humidity go hand in hand. There are big areas of the globe where high temperatures with low atmospheric humidity are to be found, and the recent war has revealed the high degree of adaptation the human organism can achieve in *such* an environment.

The record of health and work by the desert armies in North Africa was an astonishing story.

It seemed to show that, once a few weeks' tanning had been allowed, the British soldier could take almost any liberty in exposing his head and body to heat and the rays of the sun. This exposure was for many months and even years without apparently harmful effect. Though there is no doubt that evaporation of sweat played a big part in maintaining body comfort, the intake of water was often severely limited and the 'insensible perspiration' appeared to be an important factor.

The importance of a high salt intake under conditions of high temperature and low humidity was well illustrated in the Western Desert campaign by the comparison of heat exhaustion and heat cramp casualities in Tobruk and Mersa Matruh in the same 'Khamsin' (high wind with air temperatures of up to 120° to 125° F.; practically no humidity and much sand and dust). At Tobruk the saline content of the drinking water was about 450 parts per 100,000. At Mersa Matruh the saline content was about 20 parts per 100,000. Heavy manual work continued in both garrisons throughout the period. No cases of heat exhaustion or heat cramps were reported at Tobruk, but many were reported from Mersa Matruh.

Colonel Sir Sahib Singh Sokhey

I have listened with great attention and admiration to a previous speaker who showed great ingenuity in measuring temperature in the under-

surface of galvanized corrugated iron sheets used for roofing Baptist churches in West Africa, or on the inside of baked brick wall bungalows erected to house the European inspecting officers and devising steps successfully to preventing heat being transmitted to the living-room. But I have been wondering all the time why not thatched roofs and unbaked mud bricks which the natives use. It seems to me to be a better practice to utilize the empirical knowledge and practice developed over a long period of time, until we have found something positively better.

It seems to me odd that to make a man use his powers of observation at all, you first have to call him a research worker, then provide him with graph paper and a thermometer or something. Even then as soon as he puts down these exotic contrivances say, at the end of the day, he again proceeds to shut down his faculty of observation and would proceed to put himself in a boiled shirt, strangle himself with an expensive silk string, and cover himself up in thick black woollens to sit down to eat his dinner with his friends in a temperature of 120° F. in the shade. While if he had observed he would have seen that people, who live in the same area, on empirical experience wear a thin shirt or none at all and find a white loin cloth for ordinary days and a coloured one for special occasions are the most suitable clothes for sitting down to dinner.

People in the tropics are very often sufferers at the hands of fake scientists. I urge that besides accuracy of measurement we should introduce an element of realism into our investigations of physiological and psychological factors affecting life and work under tropical conditions.

THE PHYSIOLOGICAL AND PSYCHOLOGICAL FACTORS AFFECTING HUMAN LIFE AND WORK UNDER TROPICAL CONDITIONS

SUMMARY OF AUSTRALIAN POSITION

By Professor DOUGLAS H. K. LEE
(Professor of Physiology, University of Queensland)

EXISTING POSITION

GENERAL POSITION

Australia possesses the only pure Caucasian population of any magnitude living under semi-tropical to tropical conditions. The declared policy of the country is the maintenance of a 'White Australia.' Between it and over-populated countries to the north and north-west there lie no big powers capable of quick and strong defence, although the big powers are interested to varying extents in the intermediate areas. By the same token, Australia is the nearest fully civilized country to large tracts of tropical country in the Pacific area. All this places Australia in a particularly responsible and particularly vulnerable position.

Whatever else is done to meet the situation, a thorough knowledge and appreciation of the direct effects of tropical environments upon the human body are required in the first place, and the framing of administrative action in accordance with that knowledge in the second. The fact that the major population centres, and therefore of the administrative centres, in Australia have grown up in the south-eastern part of the continent, simply makes it more imperative that this knowledge be gained and appropriate action taken to develop the northern areas of Australia and its island dependencies, and to meet our other obligations in this area.

It must be realized, however, that Australia is grossly under-capitalized in manpower and that natural increase cannot be expected to bring about any rapid improvement in the situation. Until such time as the situation improves, it is essential that (i) she derive as much benefit as possible from overseas sources and (ii) that she encourage the application of her own scientific endeavour to the problems of this field. (Pure research must continue and pure research must be provided for in any planned attack as a long-range practical problem, but we are as yet too grossly under-capitalized to be entirely free with our resources.)

BASIC STUDIES

As compared with overseas activities, especially during the war, Australian studies are small in extent ; but may have a certain significance in that they deal with local subjects and actual local conditions. Studies

made upon unacclimatized English and American subjects may be applicable to the reactions of those subjects translated to hot climates, but they are not necessarily true for personnel already physiologically and psychologically at least partially acclimatized. Intermittent exposure to heat in a temperate climate does not impose the same burden as in a warm climate ; continuous residence in a room, however attractive, introduces psychological complications.

The only more-or-less continuous systematic laboratory studies in Australia upon the effects of hot atmospheres are being carried out in this department, but special investigations are carried out from time to time at the School of Public Health and Tropical Medicine and in the services. This department now has an experimental unit consisting of two air-conditioning rooms, ante-room and laboratory, equipped with basic apparatus and electronic recording devices. This is shared with workers on the corresponding aspects of animal physiology. A list of publications and reports issued to date is attached. Junior workers are maintained by annual grants but direction is entirely a part-time extra-curricular activity for those members of the university staff who may be interested.

Working conditions

Fairly close attention is given to general working conditions by the responsible governmental authorities, but, until recently, the tropical aspects have been largely neglected. The Commonwealth Department of Labour and National Service has made a close study of atmospheric conditions in textile mills, and has carried out an investigation of conditions in a Queensland factory building. A board of inquiry into the Coal Mining Industry set up a health committee which took evidence and made recommendations, amongst others upon the control of atmospheric conditions.

A fairly extensive series of investigations was carried out from this department in conjunction with the Australian Military Forces and the Royal Australian Air Force into the climatic effects upon military personnel in the tropics. The last and most extensive of these was a survey of some 1750 R.A.A.F. ground-crew personnel in various parts of New Guinea, with a view to detecting and measuring ' tropical fatigue.'

Housing

The Commonwealth Experimental Building Station is studying house design in relation to comfort, and the Council for Scientific and Industrial Research is investigating the thermal and other properties of possible new materials. The Bureau of Industry in Queensland has been considering the erection of experimental houses in Cairns and Townsville. Little, if any, original work is being done on air-conditioning.

Field studies

Now that the services are unavailable, field studies in the tropics have ceased. It may be possible to institute such studies under the civil administration of New Guinea at a later date.

Administration

Little, if any, action has been taken to bring the administration of tropical areas more into line with what is known about man's requirements.

DEVELOPMENT REQUIRED

Permanent establishment

Human climatology has been raised by the work of the war years to the realm of applied thermodynamics. For Australian work to keep pace with rapid developments elsewhere and for its applications to the numerous problems confronting this country, a permanent establishment of full-time workers with the necessary facilities is essential. Dependence upon the part-time work of a few individual enthusiasts is quite inadequate to our responsibilities. Recommendations have been made to the National Health and Medical Research Council in this connexion. This would be expensive and suitable personnel would be difficult to find, but nothing less is adequate.

Development of practical applications

Attention must be given by such an establishment not only to basic studies, but also to the proper development of the applied aspects of housing, clothing, industrial conditions, living conditions and administration (including native conditions and labour).

Co-ordination with overseas work

The fullest contact must be maintained with overseas work by international co-ordination (as suggested by the American N.R.C.), exchange of workers and frequent visits by senior responsible persons. Within the Empire, particular liaison is necessary between the Australian organization and the laboratories to be developed at Singapore and Lagos, and the R.A.F. investigators based on Farnborough.

Co-ordination with other studies

Similarly co-operation must be established with studies into the tropical aspects of animal physiology, such as those suggested to the Colonial Agricultural, Animal Health and Forestry Committee by Professor John Hammond.

DEFINITION OF THE UPPER LIMIT OF ENVIRONMENTAL WARMTH BY PSYCHOLOGICAL TESTS OF HUMAN PERFORMANCE

By Dr N. H. MACKWORTH

(Of the Medical Research Council's Applied Psychology Research Unit in the Psychological Laboratory, Cambridge)

INTRODUCTION

RECENT work for the Royal Navy included studies of the living and working conditions aboard H.M. ships, mainly from the point of view of establishing the effects of heat on human beings. The resulting laboratory hot-room investigations came under two main headings. The first problem was to find whether there was one critical point on the temperature scale above which all human performance deteriorated or whether some forms of human activity were affected more than others. An answer to this question was necessary in order to determine which compartments in the ships should have priority in the allocation of air-conditioning equipment. The resulting investigations are described in part I of this paper.

The second main aim of the research was to discover the extent of the overlap between the effects of heat on the body as assessed by physiological techniques, and the effects of heat on human performance as measured by psychological experiments. This work, given in part II of this paper, was undertaken to see how far it was possible to use simple measures of bodily functions to predict the presence of performance deterioration. Here the research aims were limited to an analysis of the relationship between rectal temperature and working efficiency, since rectal temperature is one of the measures most widely used in hot-room investigations.

PART I. DEFINITION OF THE UPPER LIMIT OF ENVIRONMENTAL WARMTH

This first and main question entailed studies of the effects of heat on a wide variety of real-life human activities. Actual human efficiency was measured with tests demanding moderately heavy physical effort, high-speed semi-automatic work, or hard thinking. Sometimes, however, a different line of approach was tried with the volunteer experimental subjects, who were mostly naval ratings. Instead of the men having too much to do, their patience was tried by giving them too little to do, as in work imitating dull and monotonous lookout duties, where accuracy of watch-keeping showed whether men could remain wide awake and alert in the heat. Conversely, the ability to sleep soundly with the minimum of restlessness was also studied at various room temperatures. These test

procedures and the results from each of the five different techniques will now be described in some detail.

1. The pursuitmeter test

Here there were two specific problems. First, do hot and moist atmospheres impair performance on tasks needing prolonged but intermittent heavy physical effort plus accurate muscular control? Second, if any such deterioration be found, how far may the atmospheric temperature be allowed to rise above the lowest room temperature obtainable with air-conditioning plant in tropical waters, before this deterioration becomes statistically definite?

Procedure

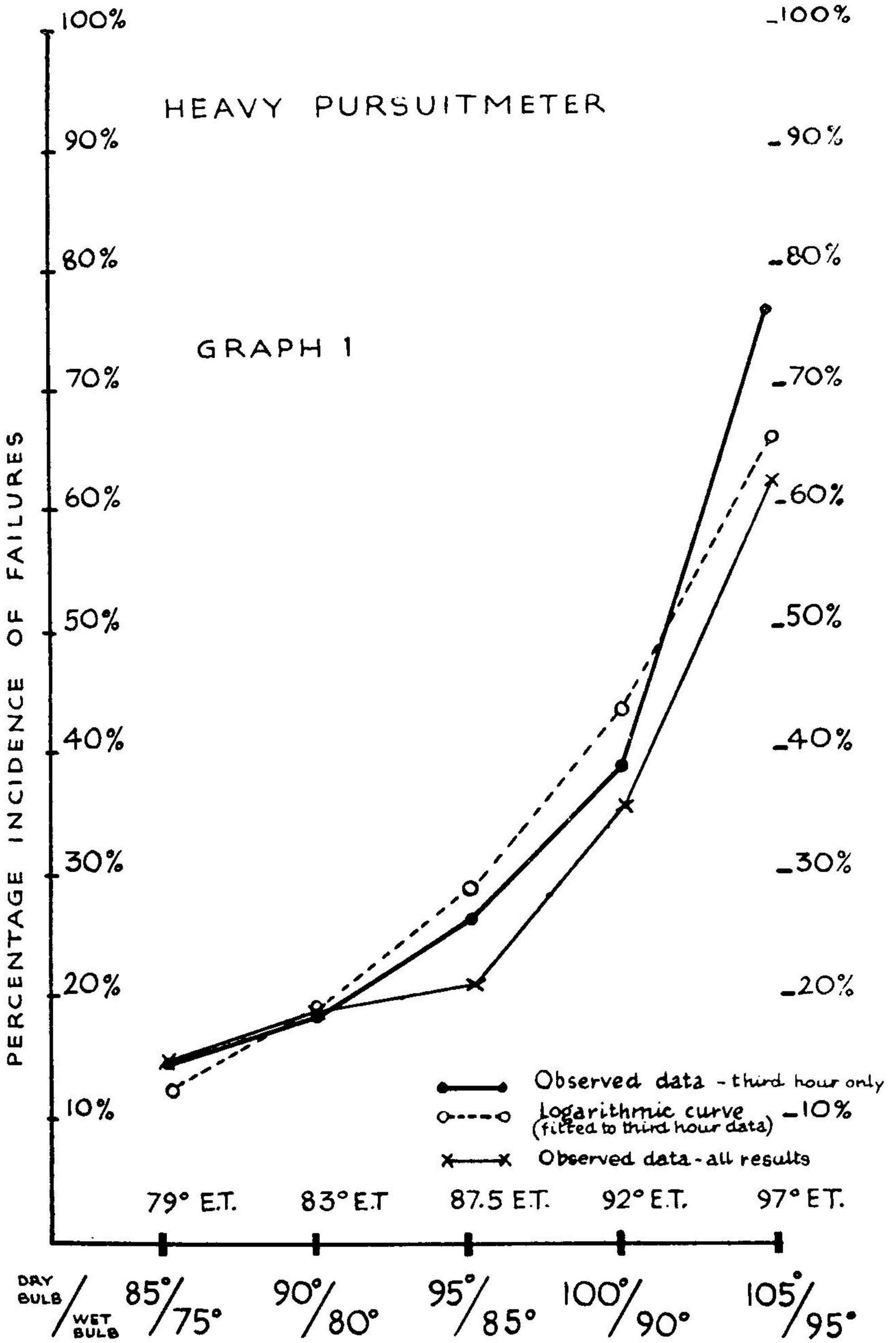
The test apparatus imparted an erratic to-and-fro movement to a mechanically controlled pointer. Using both hands, the subjects raised or lowered a horizontal lever to follow with another pointer the rapid changes in position of the machine pointer. The control lever was heavily weighted since it carried a 50 lb weight close to the subject's hands. When the two pointers were in perfect alignment, the error score remained unchanged, but a ratchet system ensured that any separation of the pointers turned an error scoring dial through an angle directly proportional to the distance between the two pointers, thereby enabling the total error score to be read at the end of the test run.

Ten physically fit young sailors between the ages of 21 and 30 were given a series of five practice spells of three minutes each at this apparatus every day for six consecutive days. These men were fully acclimatized, since they had spent 2–4 hours in humid temperatures of between 87° and 97° F. effective temperature nearly every day for one month before the main test began. The use of the effective temperature scale as an index of environmental warmth has been described by Bedford (1946).

In these tests, as in all subsequent experiments, the subject was dressed only in gym shoes and tropical shorts made from a white drill material. A sweat rag was provided for the forehead, plenty of unsalted water was at hand if required and each man had an additional daily ration of 10 grammes of salt.

The subjects were tested in two groups of five men each. On ten separate afternoons each of these groups experienced one of five different temperatures, the dry bulb/wet bulb readings being 85°/75° F., 90°/80° F., 95°/85° F., 100°/90° F., or 105°/95° F., these temperatures being held within ± 1° F. Since the air velocity in the room was always 100 feet per minute, the readings on the effective temperature scale were 79°, 83°, 87·5°, 92° and 97° F. respectively. These conditions were given in a random order to each group.

The test period on any one day lasted for three hours. The first half-hour of each of these three hours was devoted to a light task in which the subjects controlled the manual pointer with a finger control instead of the heavily weighted lever. During the second half of each hour the men worked at the heavy pursuitmeter, and throughout the whole experiment each subject alternated three minutes work on the pursuitmeter (either light or heavy) with three minutes rest.


HEAVY PURSUITMETER
GRAPH 1
PERCENTAGE INCIDENCE OF FAILURES
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
Observed data - third hour only
Logarithmic curve (fitted to third hour data)
Observed data - all results
79° E.T.
83° E.T
87.5 E.T.
92° E.T.
97° E.T.
DAY BULB / WET BULB
85°/75°
90°/80°
95°/85°
100°/90°
105°/95°
ROOM TEMPERATURE

Results

In calculating the results, the dividing line between success and failure for the individual subject was 180 errors on a three-minute run because the pursuitmeters were all calibrated to give this score in that time if no one handled the controls. Clearly, therefore, if a subject scored more than 180 errors, he was worse than useless, probably because he was making swinging over-corrections after being slow to deal with any misalignment of the pointers.

The number of readings below this standard was found for all the runs made by the group of subjects at each of the room temperatures. To this total was added the very small number of occasions on which some of the subjects felt too weak to try the test at all. The resulting grand total was taken as the number of failures at a given room temperature. This number was expressed as a percentage of the total number of test runs given the men at that room temperature ; this final figure was the failure rate, i.e. the proportion of attempts falling below the required level of efficiency.

When all the results from the heavy pursuitmeter were taken together, this failure index rose with increasing room temperature (see graph 1) and when only the last hour of the test was considered, the proportion of failures rose even more steeply with increasing atmospheric temperature.

The observed data suggested that deterioration as measured in this way bore a logarithmic relation to atmospheric temperature changes. This was tested by fitting curves of the general formula

$$\log Y = c_0 + c_1 x$$

where 'c_0' and 'c_1' were constants, 'x' room temperature and 'Y' the proportion of failures. These constants were calculated from the observed data by the usual methods. The goodness of fit of the theoretically constructed curves to the observed data was examined by the analysis of variance and found to be satisfactory, both when all the data were considered and when the third hour results were taken by themselves. The equation for the theoretical curve shown in graph 1 for the third hour results took the form

$$\log Y = 0{\cdot}91723 + 0{\cdot}17939^{x}.$$

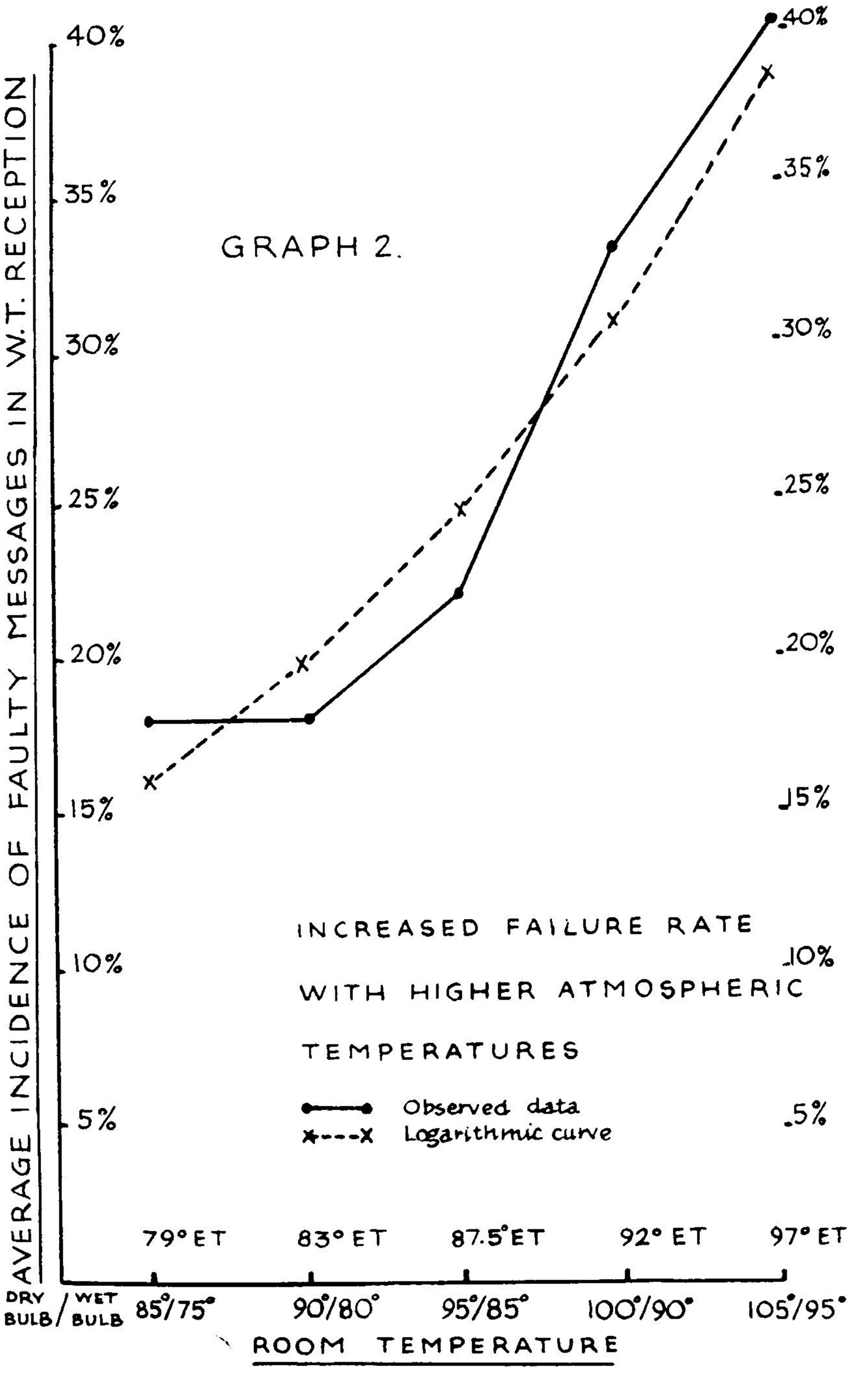
With this theoretical curve it was possible to calculate at what temperature performance was significantly worse than that obtained at 79° F. effective temperature, which was regarded as the lowest practicable temperature for work spaces in ships in the tropics. When these results from the last hour of the test were analysed by themselves, a rise from 12·9 per cent to 23·3 per cent failures was needed for a significant worsening of performance. By graphic means, this gave the effective temperature of 86° F. as the critical point at which performance definitely began to fall off compared with work at 79° F. effective temperature.

When all the results were considered together, a rise from 12·9 per cent failures to 23·8 per cent failures was needed for a significant difference, and this gave 87° F. as the critical point on the effective temperature scale.

2. WIRELESS TELEGRAPHY RECEPTION TEST

It was desirable to include in the range of tests at least one form of high-speed semiautomatic work, and a wireless telegraphy test seemed

GRAPH 2.


AVERAGE INCIDENCE OF FAULTY MESSAGES IN W.T. RECEPTION
40%
35%
30%
25%
20%
15%
10%
5%
40%
35%
30%
25%
20%
15%
10%
5%
INCREASED FAILURE RATE WITH HIGHER ATMOSPHERIC TEMPERATURES
Observed data
Logarithmic curve
79° ET
83° ET
87.5° ET
92° ET
97° ET
DRY BULB / WET BULB
85°/75°
90°/80°
95°/85°
100°/90°
105°/95°
ROOM TEMPERATURE

suitable for this purpose. A detailed account of this investigation has previously been published (Mackworth, 1946), but the main findings are summarized here so that they may be compared with the evidence from the other performance tests.

Eleven experienced wireless operators were given the task of rapidly writing down morse code messages which they heard over their headphones while working in different atmospheric temperatures. Each of these messages consisted of over a thousand symbols which were either letters or numbers. Any such message with five symbols wrong or missing was regarded as faulty, and the percentage incidence of these inaccurate messages at the different room temperatures has been given in graph 2.

The observed data again suggested that deterioration as measured in this way bore a logarathmic relation to atmospheric temperature changes. This hypothesis was tested by fitting a curve of the general formula

$$\log Y = c_0 + c_1 x$$

where 'c_0' and 'c_1' were constants, 'x' room temperature and 'Y' the incidence of faulty messages. The goodness of fit of the theoretically constructed curve to the observed data was found to be highly satisfactory and the equation for the theoretical curve shown in graph 2 was

$$\log Y = 1{\cdot}10768 + 0{\cdot}09568x$$

This theoretical curve made it possible to estimate the temperature at which accuracy was significantly worse than that obtained at an effective temperature of 79° F. A rise from 16·0 per cent failures (calculated incidence at 79° F. effective temperature) to 27·7 per cent failures was needed for a statistically definite worsening of performance.

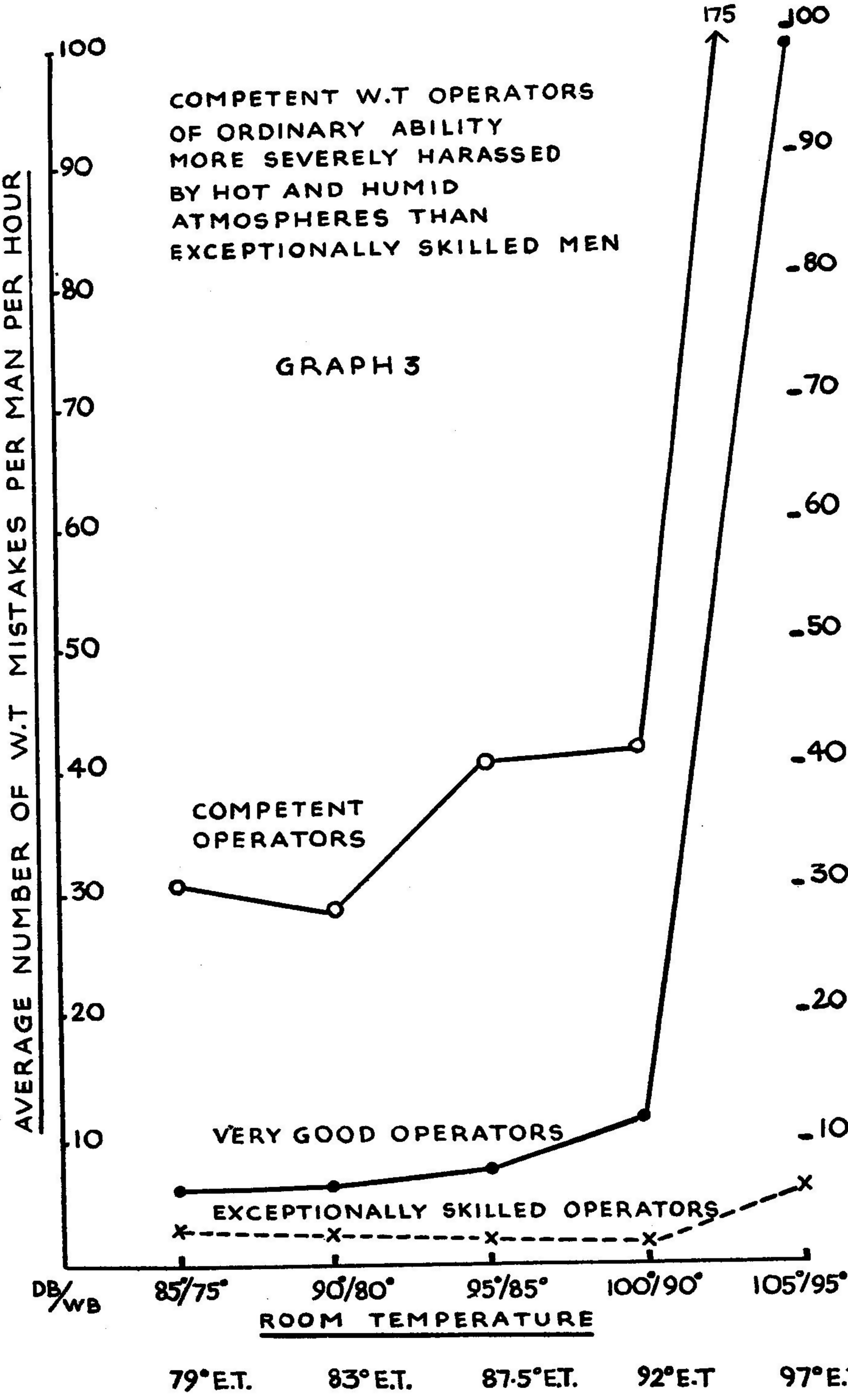
Another method of analysing the same data, however, appeared to be more sensitive to the effects of heat, since it placed the critical level for wireless telegraphy reception accuracy between the effective temperatures of 83° and 87·5° F. With this technique, in analysing the results any individual letters or numbers missing or wrong on the written answer sheets were regarded as mistakes. The average number of these errors per subject, per hour, showed a definite increase at the higher room temperatures, these readings being 12·0, 11·5, 15·3, 17·3, 94·7 mistakes for the five effective temperatures ranging as before from 79° to 97° F. inclusive. A statistical test showed that the slight difference between the average error score for the effective temperatures of 79° and 83° F. could have arisen from chance variations in the experiment, but that the increased number of mistakes between the effective temperatures of 79° and 87·5° F. was statistically quite definite, as also was the rise between 83° and 87·5° F.

The question then arose whether it was really desirable to consider all the subjects together, in view of the large differences in operating ability, even within this group of highly trained men. The subjects were therefore arranged in order of merit on the basis of their performance at the two lowest room temperatures of 79° and 83° F. The best three men were arbitrarily classed as being exceptionally skilled, the next five as very good and the last three as competent.

A study was then made of the average number of mistakes per subject, per hour, for each of these three categories under the various conditions

COMPETENT W.T OPERATORS
OF ORDINARY ABILITY
MORE SEVERELY HARASSED
BY HOT AND HUMID
ATMOSPHERES THAN
EXCEPTIONALLY SKILLED MEN

GRAPH 3



of heat and high humidity. Graph 3 illustrates the main finding which was that the level of operating efficiency of the subjects determined the extent of the work deterioration resulting from a given atmospheric temperature.

3. Coding test

Since it was felt that a more intellectual activity should also be included, a task was devised which involved a good deal of moderately hard thinking. The subjects were each provided with a form-board and a set of small flat squares which had to be arranged on this board according to a series of coded instructions. The work involved the selection of the correct squares and then their arrangement in a particular way. According to the specific instructions being followed at the time, the men had to place one large and one small square on each of five pegs, and also had to ensure that the correct side of each of the squares faced uppermost. Finally, the squares had all to be oriented on their pegs in a definite way. Many different coded instructions were available, and the subjects worked through as many as they could of these in the three hours of any one test day, setting up the boards as quickly as possible. The boards they produced were immediately checked and marked for the accuracy with which the squares had been arranged.

Results have been obtained from twelve healthy young men, all of whom had previously had two to three weeks of daily three-hour acclimatization spells in effective temperatures of 87°–97° F.; they also had had a fortnight of preliminary practice on the coding test, consisting of daily runs of about one hour each.

All twelve subjects were tested twice at each of the usual five room temperatures, and graph 4 demonstrates that the average number of mistakes per subject, per hundred boards, during the three-hour test was definitely influenced by the room temperature. A statistical analysis of the data indicated that, as before, the slight difference between the average error scores at the effective temperatures of 79° and 83° F. was due to chance factors in the experiment, but when the room temperature was raised to 87·5° F. there was a statistically significant increase in errors compared with the performance at the effective temperatures of either 79° or 83° F.

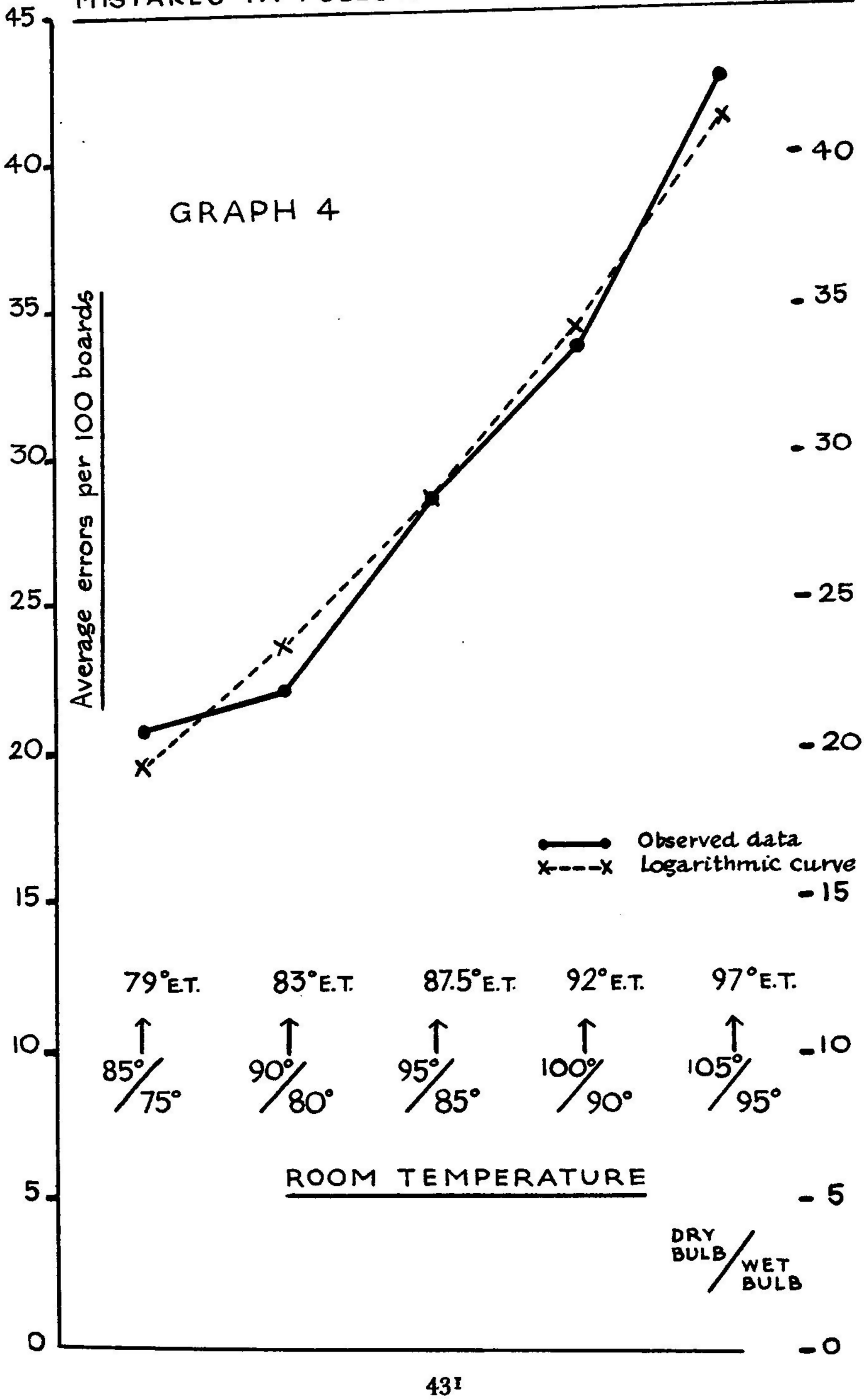
Again, the observed data suggested that the deterioration in performance, as measured by the increased incidence of mistakes in carrying out coded instructions, had a logarithmic relationship to the atmospheric temperature changes. This was tested by fitting a curve of the general formula

$$\log Y = c_0 + c_1 x$$

where 'c' and 'c_1' were constants 'x' room temperature and 'Y' the incidence of mistakes in following coded instructions. This theoretically constructed curve was fitted to the observed data and gave a highly satisfactory agreement when the goodness of fit was examined by the analysis of variance. The equation for the theoretical curve shown in graph 4 was

$$\log Y = 1{\cdot}21358 + 0{\cdot}08032x$$

It was most interesting to find three entirely different forms of work; the heavy pursuitmeter, the wireless telegraphy reception test, and the


MISTAKES IN FOLLOWING CODED INSTRUCTIONS
GRAPH 4
Average errors per 100 boards
45
40
35
30
25
20
15
10
5
0
40
35
30
25
20
15
10
5
0
Observed data
Logarithmic curve
79°E.T.
83°E.T.
87.5°E.T.
92°E.T.
97°E.T.
85°/75°
90°/80°
95°/85°
100°/90°
105°/95°
ROOM TEMPERATURE
DRY BULB/WET BULB

coding test all leading to results in which the logarithm of the index of deterioration was directly proportional to the room temperature. It seems possible that this finding is related to the general physiological principle described by Barcroft (1934) that the logarithm of the degree of activity of a vital process often correlates with the temperature at which it takes place.

From the theoretical curve in graph 4 an estimate could be made of the temperature at which the accuracy of work was significantly worse than that obtained in the effective temperature of 79° F. A rise from 19·7 mistakes (the calculated incidence at 79° F.) to 32·1 mistakes was required for a definite deterioration. This again appeared to be a method of analysing the results which was less sensitive than the technique comparing the significance of the difference between means. This graphic method placed the critical level at which coding accuracy definitely began to decline at 90° F. on the effective temperature scale, but the significance of the difference between the means put the critical level for coding accuracy between the effective temperatures of 83° and 87·5° F., a finding which was identical with the results obtained from the heavy pursuitmeter and wireless telegraphy experiments.

4. Visual attention test

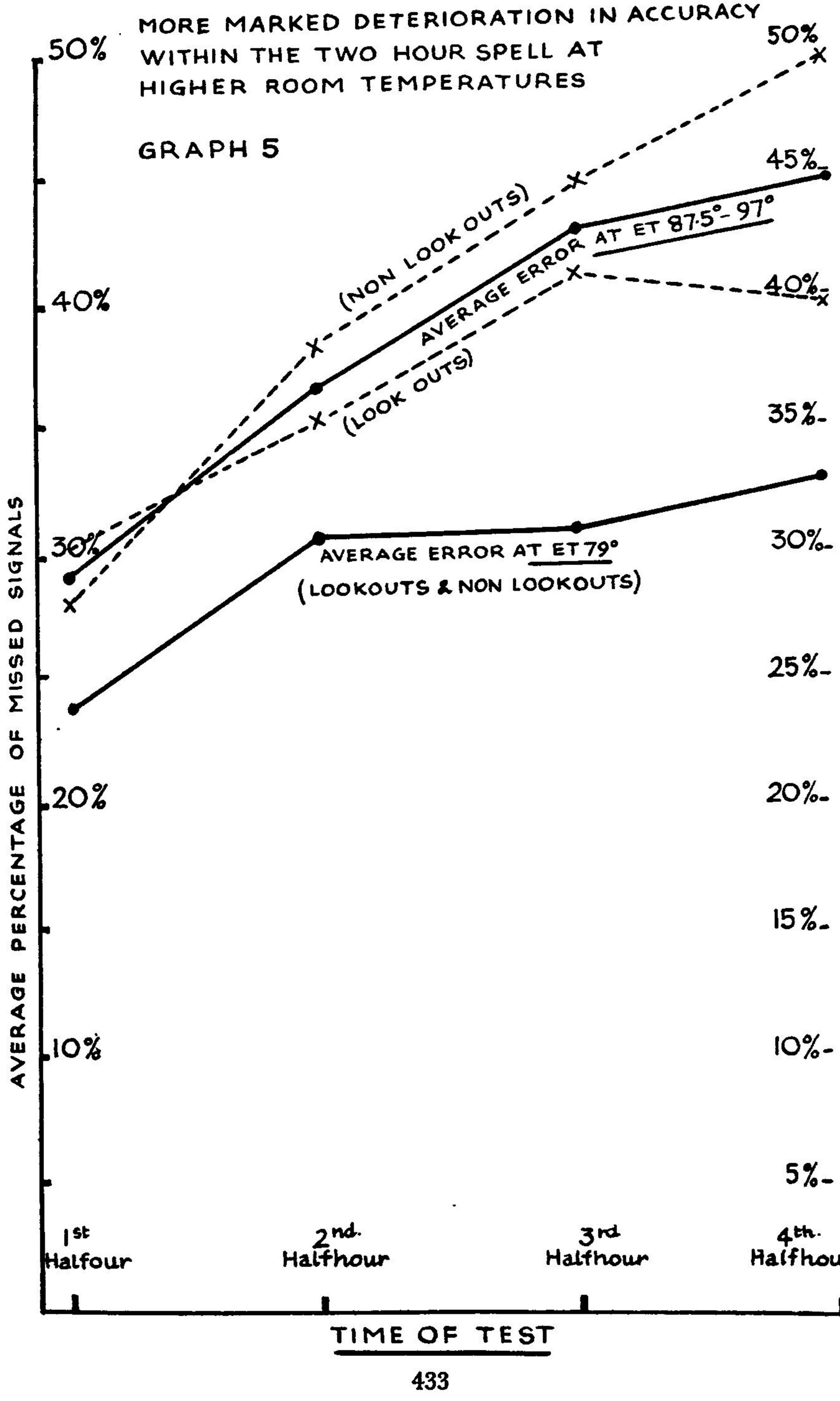
The effects of heat were also studied in a rather different situation, and this was a test of the wideawake patience and vigilance of the subjects rather than a measure of their ability to deal with a fast moving situation. The task imitated lookout duties in that the subjects worked for two hours at a test in which they reported any visual signals they could detect. These stimuli were very faint and difficult to see and appeared at long and irregular intervals. To make sure that all the subjects were familiar with the work, every man did one complete two-hour test under ordinary atmospheric conditions before his spell in the hot room. The preliminary acclimatization consisted of two hours a day for a fortnight at temperatures mostly between 92° and 97° F. on the effective temperature scale.

A suitable index of the alertness of the subjects was thought to be their accuracy of watch-keeping, i.e., the percentage incidence of signals that they failed to detect. Since the proportion of missed signals was not significantly different at the effective temperatures of 87·5° and 97° F., the results from these high effective temperatures have been combined. Graph 5 compares the average trend of deterioration within the two-hour test spell under these conditions with that found at the lower effective temperature of 79° F. The first curve was obtained from forty-six men and the second from twenty-three other subjects. It will be seen that the higher effective temperatures not only gave more errors, but also a more marked and progressive worsening of efficiency within the two hours of the test spell.

The experimental groups were planned with regard to the previous lookout experience of the ratings acting as subjects. It was arranged that at each of the atmospheric temperatures, half the men had previously been naval lookouts and half of them had not done lookout duty before. There was no difference between the lookout and non-lookout groups as regards the incidence of missed signals at the effective temperature of

MORE MARKED DETERIORATION IN ACCURACY WITHIN THE TWO HOUR SPELL AT HIGHER ROOM TEMPERATURES

GRAPH 5



79° F., but at the higher room temperatures the experienced men stood the heat better than the non-experienced. Graph 5, for example, shows the average incidence of missed signals for both the high effective temperatures of 87·5° and 97° F. taken together. When this group of results was divided into the scores made by the lookouts and those made by the non-lookouts, the differential effect of the heat plus the prolonged monotonous work became clear. During the fourth half-hour of the test the difference between the lookout and non-lookout groups was just statistically significant, but the other apparent differences were not statistically confirmed.

5. Restlessness during sleep

Some preliminary work has been done on the effects of high atmospheric temperatures on restlessness during sleep. Only six men have been studied and they have been tested nightly for about one month. After the standard preliminary acclimatization spell on the lines of that given for the visual attention test, the men began to sleep overnight in the hot room from 11 p.m. to 7 a.m., the rest of their time being spent in ambient temperatures normal for Britain during autumn and winter. The men were dressed in shorts and slept on mattresses on iron-frame beds without any bedclothes, the air movement in the room being 100 feet per minute. They began with a fortnight at an effective temperature of 79° F., and then experienced another fortnight at an effective temperature of 87·5° F.

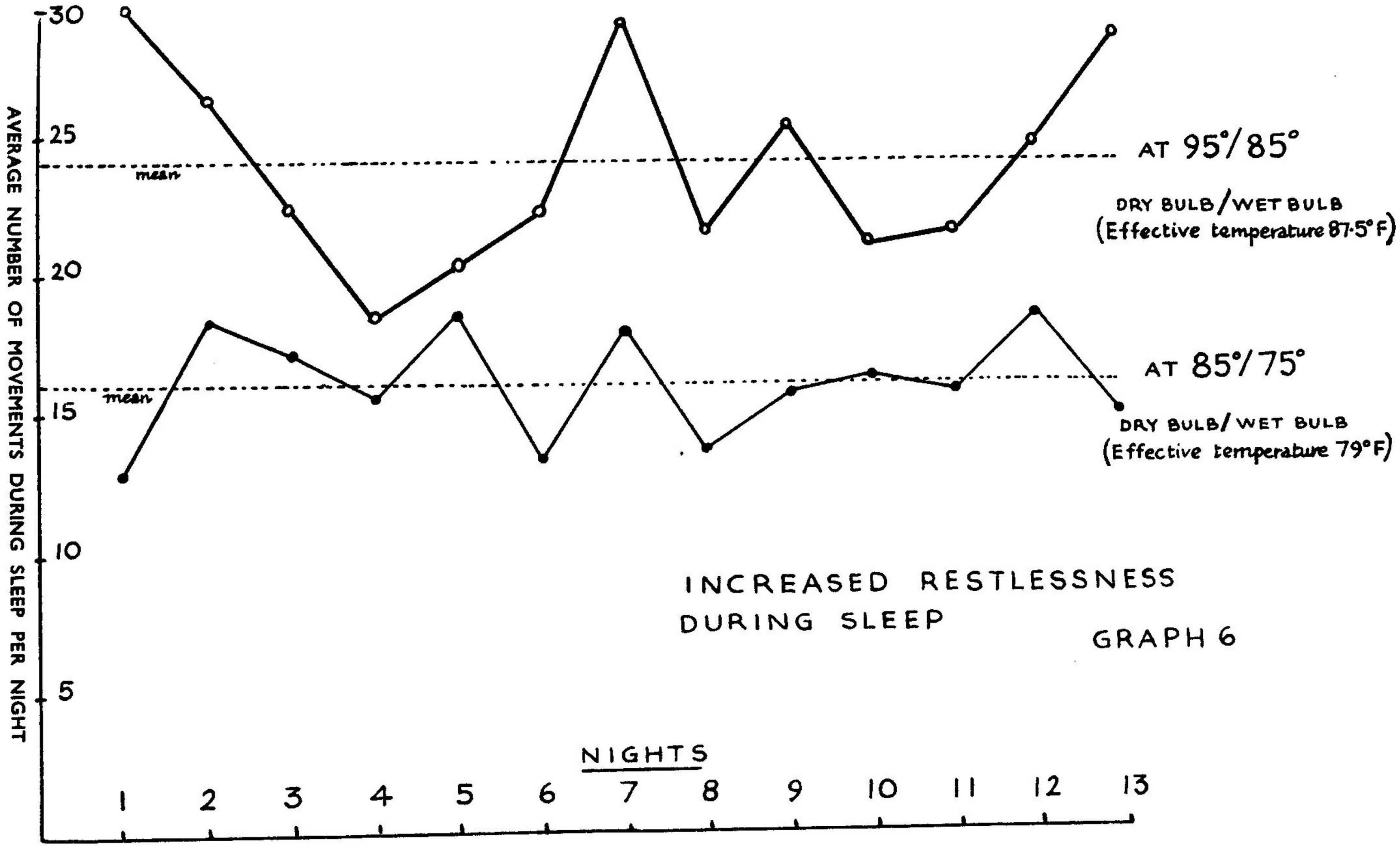
A restlessness recorder was attached to each bed and this marked a strip of paper every time one of the subjects turned over heavily. The average number of these movements per subject was calculated for the period from midnight to 7 a.m. At the 79° F. conditions this came to 16·0 movements and at the higher room temperature of 87·5° F. this figure rose to 24·0 movements. This 50 per cent increase in restlessness was statistically definite and graph 6 gives the average score on successive nights.

A similar large statistical difference was found when the temporary overnight weight loss was studied on the same subjects. At the 79° F. room temperature this reading was 1 lb 8 oz, and at the 87·5° F. room temperature it rose to exactly 3 lbs.

PART II. THE RELATIONSHIP BETWEEN RECTAL TEMPERATURE AND WORKING EFFICIENCY

There are obviously great advantages in defining the nature and extent of the association between human performance scores and measures of body function such as the rectal temperature. The work of the field investigators would undoubtedly be simplified if they could confidently use the more convenient measure of the rectal temperature to predict the possible average working efficiency of a group of men on a particular form of work.

At first, the results of this aspect of the research were rather disappointing, but recently the findings have become clearer and data have been obtained such as those shown in graph 7; these results refer to the coding test previously mentioned. As all twelve subjects were tested twice at each of



INCREASED RESTLESSNESS DURING SLEEP

GRAPH 6

the five room temperatures, 120 points are shown in the diagram. The position of each point depends on the number of coding errors made by an individual during a test period, and also upon his rectal temperature at the end of that test period. There is undoubtedly a wide scatter, but in addition there is also a definite rising trend for the average incidence of errors, i.e., when the average number of mistakes is calculated for groups of body temperature readings taken in class intervals of one degree.

The wide scatter is due to many factors, such as the marked differences between people in regard to their normal body temperature readings, and also to the great psychological differences between one man and another in regard to their ability to do this type of mental work. But some of the difficulties arising from these individual differences can be overcome by taking the average body temperature from a group of about twelve to twenty people, and by predicting from this whether, on the whole, a normal level of efficiency would be likely or not for most people.

Such average curves are available for the work performance tests already mentioned, and these are shown in graph 8. It will be seen that there was a definite similarity between the results on the sedentary tasks which were all tests of mental activity. These were the coding test, the wireless reception test and the visual attention test which have already been described ; the one new task was the electrical maintenance test, where the men were showing their ability to trace electrical circuits from wiring diagrams, the index of efficiency being the time taken to do the work correctly. All the other tests were scored on the incidence of mistakes, and graph 8 therefore shows the percentage increase on the average error score obtained at the lowest body temperature.

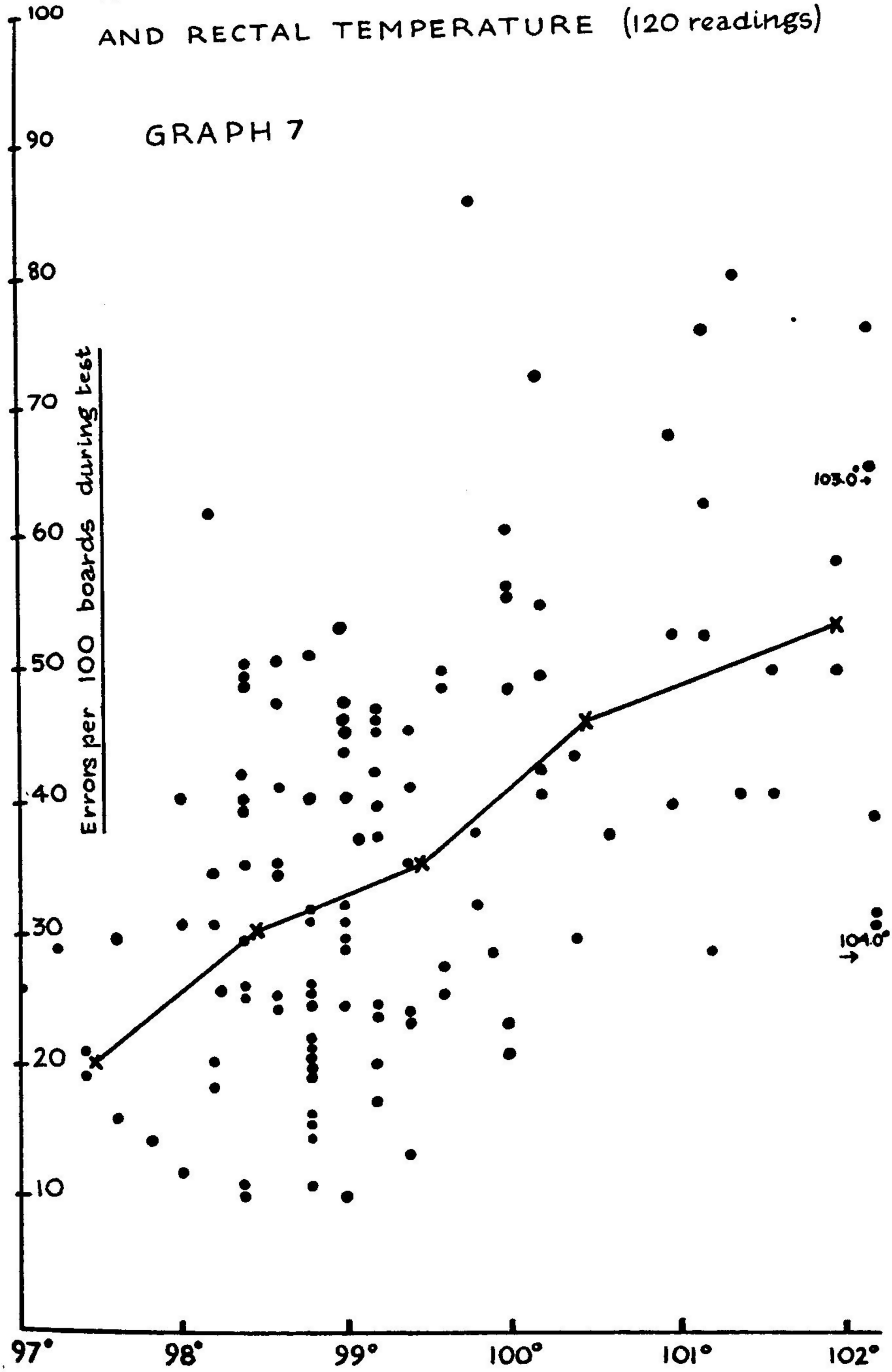
It is important to emphasize that the scatter of the individual points that made up each of these average curves, was often so great as to produce only slight degrees of association. But taking the results from these four types of sedentary work together, it looks safe to say that if a group of twelve to twenty men have been working at a sedentary task for two or three hours, and if their average rectal temperature at the end of that time is found to be more than 100° F., then, on the whole, that group of men is not likely to have been working at full efficiency.

It is unfortunate that such high rectal temperatures are only found with sedentary workers when the atmospheric temperature conditions are very severe—more severe than are usually needed to produce a statistically definite deterioration in work performance. These high rectal temperatures only occur in sedentary workers experiencing room temperatures such as dry bulb 105°/wet bulb 95° F. and sometimes in dry bulb 100°/wet bulb 90° F. (Mackworth, 1946). But if such high average rectal temperatures do occur, then this prediction of poor performance seems justified for acclimatized men doing sedentary work when dressed in shorts.

The heavy pursuitmeter results shown in graph 8 give a rather different picture from the other findings, and this is believed to be due to the fact that this test situation included a good deal of physical effort. The explanation is thought to lie in the finding that at such high room temperatures subjects usually develop a much higher rectal temperature when they are on physical work, than when they are engaged on sedentary tasks. For example, men doing physical work on the heavy pursuitmeter

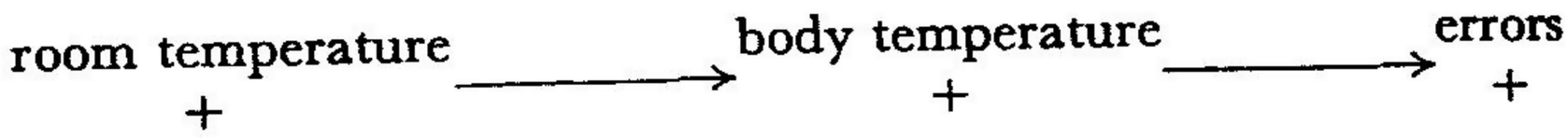
RELATIONSHIP BETWEEN CODING TEST ERRORS AND RECTAL TEMPERATURE (120 readings)

GRAPH 7



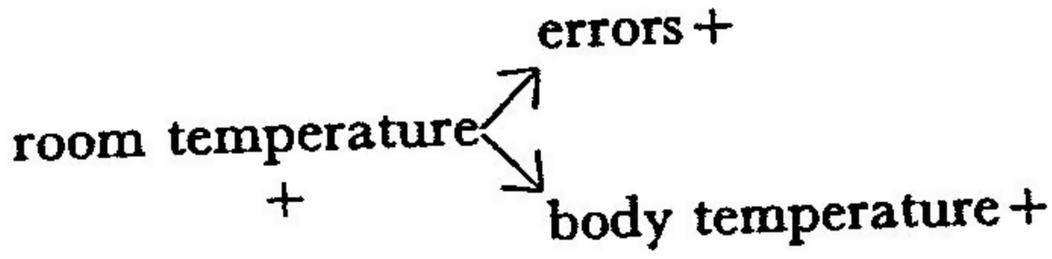
usually averaged readings about two degrees Fahrenheit higher than men on sedentary work such as the visual attention test or the wireless telegraphy reception test. Therefore, the average rectal temperature for physical workers included two degrees arising from the energy expended on the work itself, apart from the effect of the atmospheric conditions. If these additional two degrees are subtracted when one reads the average rectal temperature scale for the heavy pursuitmeter results, then the graphs for the sedentary and physical tasks become more comparable. This means that the average rectal temperature can only with difficulty be used to predict efficiency on tasks involving heavy muscular work, unless one can be quite sure how much of any given high average rectal temperature can be attributed to the physical effort involved in the work itself.

The above findings also hint at the nature of the relationship between rectal temperature and work deterioration. Supposing the relationship were *causal*, i.e. if the high room temperature were to raise the body temperature which in its turn increased the number of errors, as in the following diagram :



then the physical effort test should have been more sensitive to the effects of the atmospheric temperature changes than the sedentary, because this extra rise in body temperature due to the physical effort would logically have given a deterioration at a lower point on the room temperature scale. In fact, it has been shown in part I that this does not happen ; the critical point on the room temperature scale is the same for most types of work whether sedentary duties are involved or fairly heavy manual labour is being done.

The conclusion is that the relationship is probably *non-causal* and that the rise in room temperature separately increases the body temperature and the number of errors as in this second diagram :

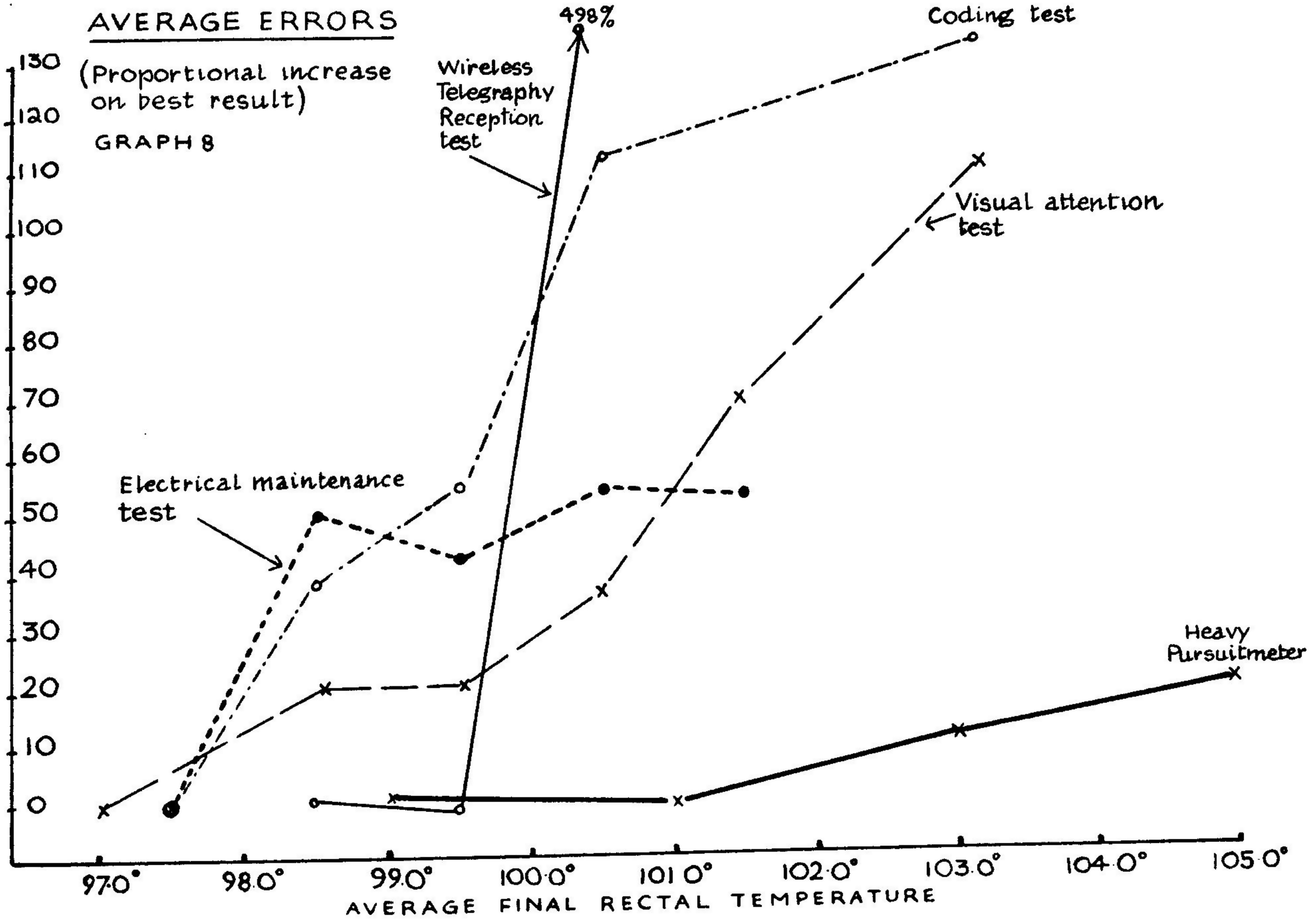


This finding has been confirmed by a statistical technique (Mackworth, 1946) by means of which it was shown for each of the performance tests in turn that the slight relationship between rectal temperature and errors in performance depended on the influence of the third or common factor of room temperature. The effects of room temperature were statistically eliminated by considering the data within only one room temperature at a time. It was found then that there was *no* relationship between rectal temperature and errors ; for example, the men with high rectal temperatures were not always those making the most mistakes, even when allowances were made for individual differences in body temperature and ability. This excluded the possibility of a causal chain of circumstances as in the first diagram, and indicated that the relationship between body temperature and errors was entirely non-causal, as in the second diagram.

AVERAGE ERRORS

(Proportional increase on best result)

GRAPH 8



Conclusions

1. There is a critical region on the room temperature scale above which most acclimatized men dressed in shorts will not work so accurately or sleep restfully. This region lies between the effective temperature readings of 83° and 87·5° F., i.e. between dry bulb/wet bulb readings of 90°/80° F. and 95°/85° F. when the air movement is 100 feet per minute. This conclusion is believed to apply to all forms of work both physical and mental.

2. The accuracy of very highly trained men suffers to a lesser extent from the effects of high atmospheric temperatures than does the performance of men of ordinary ability.

3. In three entirely different performance tests the index of deterioration has been shown to bear a logarithmic relationship to the atmospheric temperature changes. It may be that this finding is related to the general physiological principle that the logarithm of the degree of activity of a vital process often correlates with the temperature at which it takes place.

4. If a group of 12–20 men have been working at a sedentary task for two or three hours and if their average rectal temperature at the end of that time is found to be more than 100° F., then that group of men is not likely to have been working at full efficiency. This prediction refers to acclimatized men dressed in shorts and cannot be used when the task entails heavy physical effort. The finding is not therefore of great practical value, since such high rectal temperatures are only obtained with sedentary workers when the atmospheric conditions are extremely severe.

5. There is no direct relationship between rectal temperature and the incidence of mistakes ; the association is non-causal, both rectal temperature and error score being dependent on the common factor of room temperature.

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R.N.V.R. My thanks are also due to Dr E. Schuster and to Major H. C. L. Holden, R.A., who were kind enough to construct most of the test apparatus used in these experiments. Administrative help has been received from Commissioned Wardmaster Gorrie, R.N., and from Surgeon-Commander E. James, R.N., of the Medical Department of the Royal Navy, who arranged the supply of the majority of the volunteer experimental subjects.

THE PHYSIOLOGICAL STUDY OF THE EFFECTS OF HIGH ENVIRONMENTAL TEMPERATURES

By Dr J. S. WEINER
(Anthropological Laboratory, Department of Human Anatomy, Oxford)

WAR-TIME DEVELOPMENTS

STUDY in this branch of human physiology before the war was encouraged to some extent by problems in industry in which high temperatures are encountered. Following the lead of physiologists such as J. S. Haldane, Leonard Hill and C. J. Martin in this country and H. C. Bazett and D. B. Dill in America, important work was done by Vernon and Bedford in Britain and Houghton and Yaglou in the U.S.A. on problems of comfort and ventilating practice. In South Africa, Dreosti on the Rand was responsible for a notable application of physiological research to the selection and acclimatization of labourers for mining work. In Australia D. H. K. Lee, a few years before the war, embarked on a programme of research into the habitability of tropical and desert climates, mainly from the point of view of European settlement. There were, however, before the war only two climatic chambers in which active research was in progress—that of G. P. Crowden at the London School of Hygiene, and Lee at Brisbane; no experimental work was done on the Rand after 1938.

The war, as is well known, gave a powerful impetus to research in this field. By the end of 1943 the Americans had in operation no less than six separate, well-equipped teams, with considerable staffs of qualified research workers and technicians, under some of their best-known physiologists—Adolph of Rochester, the Harvard group including Johnson, Consolazio and Pitt; Sid Robinson; Ancel Keys; H. H. Mitchell; and Eichna. In Britain a new start had to be made owing to the destruction of the chamber at the London School of Hygiene by an enemy bomb in May 1941. A team was developed under the Medical Research Council and led by E. A. Carmichael in London. D. H. K. Lee's establishment in Australia represented the only other important centre for research in heat physiology in the British Empire. The Canadians, it will be recalled, devoted themselves in the climatic field particularly to cold climate problems.

An important feature of this war-time development, true of the Americans and British alike, was the ancillary investigations carried out in the field. Investigations were made in areas such as Panama, Burma, Egypt, India and New Guinea. The Royal Naval Personnel Research Committee, through its Habitability Committee, developed the use of teams of investigators at sea to a systematic degree. This background of the pre-war and war-time situation is necessary if one is to appreciate the character of the

work which has been done and assess its value both from the applied and basic physiological aspects of human physiology.

The relatively large scale on which physiological war-time research was conducted was due to the interaction of two main features—firstly, the obvious need for quick answers to a host of *ad hoc* problems affecting men living and fighting in hot climates. Secondly, and this point needs emphasis, it was realized that research in human physiology, if answers are to apply to large groups of individuals, always involves large-scale organization—the employment of dozens of subjects, provision for sleeping and feeding, often under controlled conditions, and the need for teams consisting of both qualified and 'lay' observers as well as laboratory technicians. In any discussion of future research in this field, whether for military, colonial or industrial purposes, this matter must be borne in mind. The need for relatively large-scale organization will be felt as much, if not more, in field work, especially if advantage is to be taken of available technical methods. It will be felt also in most aspects of fundamental research, since this demands combined work of a physical, chemical, hormonal and clinical character.

Outline of some results

A summary outline of some of the more noteworthy work of the last ten years, and particularly of the war years, will indicate what results are of immediate practical application (though much development work of an engineering nature is still required) and also some of the main problems which exist both in the applied and fundamental fields.

Of a general physiological nature important advances have been made in the elucidation of the following questions :

(*a*) The environmental factors which condition the performance of work at high temperatures—the relative importance of the dry bulb temperature, the wet bulb temperature and air movement.

(*b*) The physiological factors which condition the performance of work at high temperatures—the level of work, fitness and acclimatization, clothing.

(*c*) The limits of tolerance which can be prescribed for work done in enclosed spaces in tropical environments. The value of the American effective temperature scale is now better understood.

(*d*) The underlying physiology of adaptation and acclimatization has been studied even during pressure of war-work. Data have been obtained on some phenomena of the circulatory, heat-regulative and endocrinological systems.

(*e*) Salt and water metabolism has been studied both in the laboratory and in its clinical aspects in relation to dehydration and salt deficiency, notably by Ladell and Waterlow in Iraq and Adolph in America. The rôle of the kidney and of the sweat glands has also received attention.

(*f*) Intensive study of the composition of sweat has been carried out in America in relation to nutritional problems by Keys and by Mitchell.

(*g*) A beginning has been made in the study of tanning, sunburn, etc.

The practical *ad hoc* research, to which the above was on the whole subordinated during the war, and which is capable of industrial and civil application, concerned mainly the following :

(*a*) The application to ventilation and air-conditioning practice of the knowledge gained regarding limits of tolerance. In this connexion study has been made of spot cooling and particularly of personal cooling as suggested by Houghton in U.S. Its development in relation to mining operations has been proposed by McArdle and the writer.

(*b*) The incidence of various types of heat exhaustion and their treatment.

(*c*) Fabrics and the design of clothing for tropical service ; the relation of tropical clothing to malaria prevention.

This brief survey will serve to indicate the main lines of future applied and basic research. The fact that in the applied field the physiologist will be inevitably needed in the habitability problems of the future industries of the tropics requires no further emphasis.

Future organization of research

Bearing in mind the twofold nature of the research—the fact that one is concerned with a major branch of human physiology on the one hand and bio-engineering on the other—the appropriate organization would, on the whole, have to be similar to the war-time schemes, with certain important modifications and changes of emphasis. Field work is of utmost importance, especially for problems of hygiene and habitability, and in future will require fairly well-equipped laboratories in suitable centres in the tropics. These will be required to undertake more ambitious programmes than was possible to the war-time field or sea units. The need to extend fundamental physiological research will have to be the first concern of laboratories necessarily situated in well-established research centres. Of the ' field bases,' West Africa and Singapore have been projected as suitable centres. For ' home bases,' there is Lee's laboratory in Australia, the laboratory at Oxford and the future facilities which may become available under the Medical Research Council and elsewhere. If these plans are implemented, an adequate organization, even if not as imposing numerically as the American set-up, will have been created.

Empire co-operation

This leads to the question of collaboration and integration. It may well be that this will come about quite naturally as the various centres develop, since a fair degree of official and unofficial co-ordination remains from the war ; it may be thought by some that a definite body needs to be set up soon for the Empire. Undoubtedly, Empire co-operation would be needed to implement proposals such as the following :

(*a*) Joint research by Dominions and Colonies interested, at field stations.

(*b*) The provision of fellowships for Colonial medical graduates for a tenure of research at climatological laboratories, in this country or in Australia.

(*c*) The provision of refresher courses for Colonial medical officers which will include the physiology and hygiene of high temperature climatology.

(*d*) A joint participation by the Empire countries interested, in a research association concerned with the engineering aspects—to operate both at home and in the field on problems of habitability of an industrial, military and domestic character.

MORNING SUBJECT (b, ii)

A SURVEY OF SOME OUTSTANDING PROBLEMS IN MEDICAL SCIENCE. THE ETIOLOGY AND CONTROL OF INFECTIOUS AND TRANSMISSIBLE DISEASES, PARTICULARLY THOSE WHICH ARE INSECT-BORNE

STEERING GROUP

Chairman—Professor C. E. Hercus

Recorder—Dr C. H. Andrewes, F.R.S.

Dr I. B. Bull
Professor A. T. Cameron
Professor W. E. Le Gros Clark, F.R.S.
Dr E. H. Cluver
Professor W. A. E. Karunaratne
Sir Edward Mellanby, F.R.S.
Colonel Sir S. S. Sokhey

REPORT

This discussion was prompted by an awareness that many parts of the Empire were apparently vulnerable to attack by epidemic diseases not already existing there. More knowledge was required as to the ecology of infectious agents of disease, in order to judge when there was a real threat of spread and when fears were unjustified. There was a dearth of entomologists, medical and otherwise, and of zoologists generally, to co-operate in such studies. In many regions insect-borne diseases only occurred over part of the area in which the insect vector occurred.

Yellow Fever. Yellow Fever stopped at, or short of, the eastern coast of Africa and did not extend into India and Malaya, though the transmitting mosquito, *Aëdes aegypti*, extended all over these areas. Introduction of yellow fever into India might lead to a major disaster. Traffic between Africa and Asia had gone on for a long time : the speed of transport, however, affected the issue. With slower methods, a traveller incubating a disease such as yellow fever would develop it and cease to be infectious before he reached another country. More dangerous than infected persons were infected arthropods, especially mosquitoes. These were more likely to survive when transport was rapid. Regulations were in force to ensure the freeing of aeroplanes from insects carried by them ; but these regulations were carried out by local authorities with varying degrees of efficiency and enthusiasm. The precautions might be reduced to a perfunctory and quite useless two puffs with a Flit-gun. An elementary precaution would be to close doors and windows of planes standing on aerodromes at night : it was then that mosquitoes sought refuge in them. An international authority was needed to see that vaccination was carried out where required, that the vaccines used were efficient, that sanitary measures at aerodromes were carried out to keep down the numbers of insects there and that freeing of aeroplanes from insects was conducted efficiently.

Malaria. There was a serious risk of widespread distribution of malaria in Australia by troops returning from New Guinea. Intensive drug treatment, particularly with mepacrine, reduced the danger to small proportions. The new drug, paludrine, promised to be even more useful. One or two doses a week acted as a causal prophylactic against malignant tertian malaria and suppressed the activity of benign tertian. The drug might be used to clear malaria out of populations in the tropics which had never enjoyed healthy and vigorous childhood. There was discussion as to whether or not there was danger, in attempting this, of producing a

drug-resistant race of parasites. The view was expressed that the danger was particularly great if a drug were used on such a large scale that nearly every parasite was exposed to its action.

Sandflies had rather limited distribution, though areas apparently suitable for them were much more extensive. They could fly only short distances but could go several days without food. There were obvious dangers of introducing them by means of aeroplanes into fresh regions. Diseases transmitted by them occurred both in the old world (sandfly fever and kala-azar) and new world (Oroya fever) ; it was not known whether or not Oroya fever could be transmitted by old world sandflies or whether there was or was not accordingly a danger of introducing the disease into the Mediterranean.

Cholera was endemic only in limited areas, especially Lower Bengal and the Yang-tse Valley ; whence it spread periodically. The reasons for its persistence only in some areas was not known, nor the form in which it survived, for its persistence in human carriers and in water was apparently brief. Co-operation with China was called for to limit the disease, in the first instance, to the endemic areas.

Plague was similarly spread from very limited foci, particularly along the west coast of India and at the foot of the Himalayas. The problem was to stamp out the disease in these foci. It was emphasized that we had all the knowledge necessary to abolish plague but lacked only the will to apply the knowledge.

At the conclusion of the discussion, it was emphasized that success in controlling infectious disease must be accompanied by the solving of the problems of population and nutrition. If science were too successful in controlling infection, famine might take its place.

General recommendations

1. The Conference, having regard to the present state of knowledge of the ecology of infectious diseases, feels that there are grave dangers of spread from one part of the Empire to another and within certain Empire countries. Particular attention was drawn to malaria, yellow fever, schistosomiasis, trypanosomiasis, plague, cholera, and diseases spread by sandflies.
2. More knowledge of the ecology of infectious diseases, their arthropod vectors, their reservoir hosts and the reasons for the persistence of infection in localized endemic areas is needed. The attention of universities and other authorities should be drawn to the need in many parts of the Empire for ecologists and entomologists, both medical and non-medical.

Special recommendations

1. That an international organization should be established under U.N.O. to prevent the spread of diseases from endemic to non-endemic areas. Such an organization would :
   (a) Control vaccination and inoculation in connexion with diseases to which these or other such precautions may be held to be applicable.

(b) Ensure the freedom of aeroplanes, aerodromes, ships and other facilities for travel between different countries, from insects and other media of infection.

(c) Secure uniformity in regulations regarding certificates required by travellers between different countries.

(d) Devise such methods of administration as would avoid vexatious and unnecessary impediments to the movement of travellers or goods.

The Conference notes that existing regulations at airports and other transit centres are unsatisfactory owing to a shortage of trained sanitary inspectors and other medical personnel. It would draw attention to the availability of a substantial pool of junior personnel suitable for recruitment into the required sanitary service, among ex-service men and women, particularly in India and the Colonies.

2. For the prevention of the spread of certain diseases from endemic to non-endemic areas within particular countries, the Conference urges that local and permanent organizations are required for containing and controlling the diseases in the endemic areas. Particular reference is made to cholera and plague.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr D. M. Blair

There is a distinct tendency for public health measures to become more restrictive and the objects for which enforcement is asked, lost sight of.

This is particularly so in the field of international health where lip service is paid to requirements or conversely public health measures are used in a restrictive sense to prevent the free movement of persons not on health grounds, but for reasons of immigration policy or politics.

As an example of the misuse of the requirements of international health regulations I should like to quote the following example. Shipping firms in South Africa before accepting passengers for the direct service to Buenos Ayres require a valid yellow fever certificate. This is done presumably because it is easier to ask all passengers to produce such certificates wherever they may be sailing, but what inconvenience to the traveller.

As an example of the lack of co-ordination between the broad principles of the International Sanitary Convention for Aerial Navigation and the detailed measures required at each aerodrome in and around the yellow fever areas, any observant air passenger can supply instances of such ineffective measures that it is doubtful whether the effort that is expended is really worth while. I would draw attention to the following matters of practical detail :

1. It is rare to see an aeroplane which is to remain all night on the ground completely closed up to prevent the ingress of insects.

2. Spraying should be done during flight and soon after the take-off so that a prolonged effect can be obtained on all airborne insects. It should be possible to achieve the same effect either by a D.D.T. residual film applied to all internal surfaces in the fuselage, or by an insecticide spray distributed by fine tubing throughout the aircraft.

3. If hand spraying or pressure spraying of insecticides is to be done immediately on touching down it must be carried out in a closed space and done in all sections of the aircraft, a very unpleasant and tedious procedure which stirs crew and passengers to rebellion.

Dr F. M. Burnet

In opening a discussion on the problems of infectious disease, particularly arthropod-borne disease within the Empire, I am naturally rather overwhelmed by the possible scope of such a subject. In accordance with the direction of the steering committee I wish to concentrate on the problem, not from the point of view of dealing with existing infectious disease, but rather by thinking of what may be done to prevent the *entry* of infectious disease into areas not now infected. In attempting to look for general

statements that might be applicable to such an approach I am very conscious of the necessity in any problem of infectious disease for the closest possible study of the specific disease we are concerned with. Argument from analogy with any other disease is always liable to be dangerous.

Nevertheless, if this proviso is constantly borne in mind, it is, I think, possible to present the position in fairly general terms. Looked at from the ecological point of view infectious diseases of man fall into two major groups : (*a*) those in which the standard mode by which the pathogenic organism survives as a species is as a human parasite or commensal, and (*b*) those diseases which represent an essentially accidental invasion of the human body by a micro-organism which survives as a species in some different biological environment.

In the first group we have in addition to strict parasites other micro-organisms which are normally harmless commensals but which under special circumstances can be responsible for disease. We may instance as members of this group the viruses of measles, influenza and smallpox, the cholera vibrio, the diphtheria bacillus, the haemolytic type A streptococci, the *Treponema pallidum* and the malarial parasites.

In the second group we have as typical examples from different fields :

Scrub typhus, the mosquito-borne encephalitides and psittacosis. Here the micro-organism has evolved in a biological environment in which man plays no part.

There are, of course, intermediates. A micro-organism whose natural habitat is some animal or arthropod may become capable under certain circumstances of taking on a more strictly human parasitism. The hypothesis of Turssen is well known, that epidemic typhus, the disease transmitted from man to man by the louse, is derived from the related disease marine typhus with the rat as reservoir and the rat flea as vector. Psittacosis is normally contracted only from parrots or other birds, but on occasion quite startling hospital outbreaks have occurred with a chain of cases in doctors and nurses. Yellow fever is another example. Aedes-spread yellow fever of the African and West Indian ports was almost certainly a derivative of jungle yellow fever in which man plays no essential part in the survival of the virus.

Every infectious disease irrespective of whether it is as easy to understand superficially as mumps and measles or as difficult as malaria and scrub typhus is a manifestation of a complex ecological situation in which at least two and often several living species are interacting.

Particularly in the arthropod-borne diseases a full understanding of the ecological situation is essential both for control and for any intelligent forecasting of potential developments.

The primary problem before us may be put as follows. There exists on the globe a wide variety of living agents which can under appropriate conditions produce disease in man. The actual incidence and character of infectious disease varies greatly from one part of the Empire or of the world to another. Is it possible to state for each or any of these diseases whether it could appear and maintain itself in areas not now involved and if so what are the appropriate means to prevent such extension ?

There are some diseases known to be capable in the past of almost

universal spread, but which are now easily amenable to control in civilized temperate climates ; smallpox, cholera and other major intestinal diseases, plague. There are others which are still almost universally present notably the respiratory infections, including diphtheria and poliomyelitis. Both groups can be almost eliminated from discussion.

The practical problems concern :

(*a*) Those areas at present free from a certain disease in which the ecological situation is such that the disease in question might spread easily if introduced.

Two examples from my own country are rabies which might well become established amongst the dingoes and wild dogs of Australia, and the mosquito borne encephalitides. There is a strong presumption that a highly fatal human encephalitis present in 1915–1917 and again in 1925 in the inland regions of Australia was due to a virus related to the viruses of louping ill or Japanese B encephalitis and like them carried by an arthropod vector. We do not know the reasons for the appearance and disappearance of the disease, but its history is such as to suggest that Australia might well be vulnerable to the introduction of viruses of this type. The most important of these problems, the possibility of introducing yellow fever into the eastern tropics, will be dealt with by Dr Findlay.

(*b*) The possibility that the ecological situation may be modified by human action to allow the spread of a disease which cannot now do so. The introduction of *Anopheles gambiae* into Brazil with subsequent severe malarial epidemics is one example—there are many instances in which various types of drainage and irrigation works have destroyed the ecological balance and allowed the appearance of severe malaria in regions where it was previously absent or trivial.

On a much smaller scale one may note how the development of a budgerigar breeding industry in California increased and concentrated the likelihood of human psittacosis in U.S.A.

Or how certain local circumstances restricted the rickettsial disease Q fever almost wholly to the employees of a Brisbane abattoir.

(*c*) A most important but at present intangible problem concerns the appearance of unduly virulent varieties of well known endemic diseases. In 1857 diphtheria suddenly or apparently suddenly took on a new intensity and the disease spread rapidly over the world. In 1918 influenza took on a character which may probably be interpreted as a mutation towards greater virulence followed by a series of further mutations facilitated by the immense temporary success of the first. In 1937 a strain of poliomyelitis virus appeared in a Melbourne suburb and spread from a single schoolroom to produce 2,000 to 3,000 cases in the most severe epidemic in Australian history. The study of variation in micro-organisms is very active at present—almost a new branch of genetics is in process of formulation—but it is doubtful whether any method of predicting significant changes will ever be possible. The possibility of deliberately producing strains of enhanced human virulence is not so remote. It is probably safe to say that future calamitous epidemics in civilized countries, irrespective of whether they are produced as part of a new technique of war or arise by natural mutation, will be in the field of the airborne infections.

The types of control required in the field we are considering can be summarized as :

(*a*) the prevention by appropriate measures of the entry of infection into vulnerable areas.

(*b*) a continuous watch on the ecological situation as it may be modified by the introduction of animals or plants by civil engineering projects or by changed methods of agriculture or animal husbandry.

(*c*) as far as unduly virulent appearances of endemic respiratory disease is concerned the need is for the further development of preventive and chemotherapeutic measures at present available, for research into the nature of micro-organismal variation and for the study of the possibilities of effective quarantine against respiratory infections. A very interesting problem (which with modern means might well be soluble) would be presented if the conditions of October 1918 to February 1919, recurred in Australian ports. For those five months, persons were ill and some dying of pandemic influenza in Australian quarantine stations without apparent escape into the general community.

I would close by repeating my opening statement that generalization about infectious disease can provide no more than the roughest outline. Each situation will need to be studied in detail as it occurs—always with the realization that effective action will rarely be possible without a full understanding of the ecological situation.

Professor B. G. MAEGRAITH

To be a successful anti-malarial, Paludrine should be (i) non-toxic in therapeutic dosage and (ii) non-toxic after administration over long periods as a suppressive.

The immediate toxic effects of dosage with Paludrine have been closely observed both in Cairns and Liverpool. In Liverpool the dosage was started at 20 mg. 12 hourly and gradually increased by increments up to 750 mg. 12 hourly for fourteen days. During these experiments a watch was kept for harmful side-effects. Over the whole range of dosage no serious side-effects were observed. Vomiting half to one hour after administration were noted in a few patients, with doses of 500 mg. or more 12 hourly, but on smaller doses which were equally active therapeutically, nothing was observed except occasional slight nausea. Our results have been confirmed by the Australian workers. Paludrine has therefore been shown to be non-toxic over a very wide range of dosage.

All the evidence available indicates that Paludrine will prove equally non-toxic after long administration, but we have only incomplete information on this point. The amount required for suppression is very small ; the drug is excreted rapidly in the urine ; it disappears rapidly from the bloodstream after a course of treatment has been stopped, indicating that it is not fixed for any length of time in the tissues. A good many patients have now been taking the drug in suppressive doses without ill effects for some months. All this suggests that ill effects after long continued dosage

are unlikely to appear. Nevertheless it would be worth while to seek more direct evidence on this point. A big scale field trial is already going on and the results of this will settle the practical point. A more detailed biochemical study of a small group of subjects would be helpful, on the lines of the experiment we carried out during the war with mepacrine, which was designed to follow various organ functions in volunteers taking suppressive doses over a period of ten to fifteen months. In the case of mapacrine we were able to show that regular dosage over such a period did not have any detectable deleterious effects on kidney or liver function, or on the bone marrow. A similar experiment with Paludrine should be carried out. The difficulty is that such work requires highly organized teamwork and a plentiful supply of volunteers. These things were obtainable during the war. They are more difficult to obtain in peace. The difficulty lies less in the formation of teams, than in the availability of volunteers. For the mepacrine work we used Oxford undergraduates. It may be possible to use similar undergraduate bodies again, but it will be difficult. Could not the inmates of prisons be asked to volunteer for such purposes? I believe such communities were used successfully in America during the war.

Colonel Sir SAHIB SINGH SOKHEY

Bubonic Plague. In connexion with this infection the most important consideration to be noted is its changed status as a world pandemic during modern times. Plague is the oldest of known epidemics. It can be traced in historical records further back than any other known disease. Plague raged in different parts of the world from time to time and exacted a very heavy toll of life. During historical times, before the present pandemic, Europe was visited by two severe pandemics, one in the sixth and the other in the fourteenth century. The first of these pandemics started in A.D. 542 in Eygpt, it spread along the coast of North Africa on one side and along Syria and Palestine on the other, and ultimately affected the whole Roman Empire. The important point is that it raged in Europe for about 200 years and caused a very heavy loss of life. The second pandemic started about the year 1347. It was first noted in the Crimea and is believed to have originated in Central Asia, reaching the Near East either by way of China or India or both. It spread to Asia Minor, North Africa and the continent of Europe. This pandemic again lasted for over two centuries in Europe and caused great loss of life. In two years from 1347–1349, it is said to have killed more than half the inhabitants of Western Europe.

Now look at the present pandemic. In 1894, plague spread from Yunan to Caulin and Hongkong. From there it spread to Bombay and the rest of India, and in the course of a few years the disease became very widespread involving many parts of the world, like Australia, South Africa, North and South America, Egypt and several Mediterranean ports. Cases also occurred in the British Isles at Glasgow, Cardiff, Liverpool and London. But it is to be noted that though enough plague reached Europe it did not take root there, and very few casualties occurred, while the whole of India was soon invaded and in 1904 as many as 1,143,993 deaths occurred, up to now more than 12½ million deaths have occurred in India. The immunity of Europe to plague cannot be attributed to any deliberate steps

taken, though the cause of the disease had been found to be a bacillus, precious little was known about its epidemiology and steps taken by the sanitary authorities did not in any sense control the spread of the disease. Greenfield went so far as to say that ' indeed the discovery (of the plague bacillus) may have done temporary harm, because people were set to trace the dissemination of the germ and at first they looked in all the wrong places.' Thus the inability of the plague to take root in Europe cannot be explained by any preventive steps deliberately adopted. It therefore emerges that the most important factor which seems to have proved effective in preventing plague from spreading in Europe was the material prosperity which the continent experienced before the two pandemics, leading to great improvement in the housing conditions of the people.

The ideal step to prevent this disease from breaking out anywhere would be to provide all the people with suitable houses. But with the present private profit dominated structure of society this solution will have to wait long. Even short of this ideal solution our knowledge of the epidemiology of this infection has in recent years become so comprehensive that if we organize to make use of it no epidemics need occur at all, and any stray cases occurring could be effectively treated. We know now how epizootics start at a place and how they ultimately come to an end of their own accord, what are the reservoirs of plague and how epizootics and epidemics spread from these reservoirs to other places. In addition we now have effective curative agents against plague and our newer plague vaccines give very high immunity against the disease.

Indian work has shown that the rodent responsible for the spread of the disease to man, the black house rat (*Rattus rattus*) is highly susceptible to the infection at the start of a pandemic and the epizootics go on continuously and intermittently until almost all the susceptible strains of the rodent die out. For instance in the city of Bombay, a few years after the outbreak of the pandemic, I believe in 1904, 90 per cent of the house rats were found to be susceptible. In 1932, only about 9 per cent were susceptible and during that year about 700 house rats were found to have died of plague from among 700,000 rats examined during the year. In 1933 about 7 per cent were susceptible and that year about 500 house rats had died of plague out of a similar number examined during this year as during the previous year ; and so on until in 1936, rats examined were completely resistant to plague and none was found to have died of plague out of about 700,000 examined. Since that year every year about the same number of rats have been examined, but no plague infected rats have been found appearing that the epizootic had come to an end in 1936. But since that year the susceptibility of house rats had steadily begun to increase, for instance it was about 3 per cent in 1937, about 5 per cent in 1938, and so on until in 1945 it was about 15 per cent. It is to be noted that while this low degree of epizootic was going on no cases of human plague had occurred in Bombay for over twenty-five years.

It has also been found that it is possible to map out areas, usually situated in watersheds at the foot of hilly tracts, where climatic and soil conditions are of a certain type, where slow smouldering epizootics go on continuously in this, necessarily giving rise to epidemics. From these tracts the infection is conveyed with merchandise, most often grain to the plains where explosive

epizootics and epidemics break out only completely to die out with onset of hot weather. Sylvetic plague is not known to occur in India.

It is therefore necessary that permanent organizations should be set up to map out such areas and take steps to prevent the infection from spreading to other areas and concentrating in anti-rodent measures in these endemic areas.

THE SPREAD OF INFLUENZA AND ENCEPHALITIS

By Dr C. H. ANDREWES, F.R.S.

I WISH to speak briefly about two virus-diseases, or groups of diseases, of which the spread from country to country may have unpleasant consequences—influenza and insect-transmitted encephalitis.

INFLUENZA

There are two apparently conflicting views as to the epidemiology of influenza, and I am beginning to suspect that both of them may be right. According to one view, influenza always reaches a country from somewhere else. Epidemics over here have thus been called the Russian or the Spanish, or some other kind of influenza according to their supposed place of origin. Outbreaks in Britain usually last for at most three months, and influenza virus A—the more important of the two known influenza viruses—may not be recognized at all in this country for the twenty-one months or so before another outbreak occurs. Can we believe that its normal existence consists of a progression round the world, producing epidemics, passing from the northern to the southern hemisphere and back again according to season? Recorded data as to the periodicity of influenza in different parts of the world do not at all support such a view: epidemics in Britain, on the European continent and in North America tend to occur at about the same time, but there has been no discernible regular relation to those in the southern hemisphere. Country to country spread of pandemic influenza, as in 1918, is another matter, to which I shall return.

The second view supposes that the influenza viruses are always with us, perhaps in the respiratory tracts of some people who are carriers, perhaps causing, between epidemics, subclinical infections or sporadic respiratory ailments which do not get called influenza. And then, after the lapse of time the immunity of the population wanes to a suitably low level, and some climatic or other as yet undefined factor sets the stage for a greater or lesser outbreak. An argument for such a view is the occurrence, as in Britain in 1937, of a number of antigenically distinct variants of influenza virus A, all in one outbreak. There are, too, a number of examples on record in which viruses A and B have turned up in one and the same epidemic. Shope has made out a very strong case for believing in the genesis of an outbreak of swine influenza by simultaneous activation of latent virus in a number of separate droves of pigs. There is good evidence that the virus may be carried in the pig lung worm; this passes part of its life cycle in earthworms; the virus may get back into the pigs' lungs when pigs eat such infested earthworms, but virus so seeded into a drove of pigs will not produce an epidemic until some outside, perhaps climatic, conditions are favourable. Then up comes the epidemic, occurring at the same time in lots of farms between which there is no contact likely to be capable of spreading the infection.

I confess that I was practically convinced of the truth of this latter view of the endogenous origin of human influenza epidemics. But the behaviour of influenza virus B during the last year has rather shaken me. It seems that this virus began causing trouble in June 1945 in Hawaii and Guam. Thereafter it spread east, and epidemics, all mild ones, appeared in the next few months in the Caribbean area, the more northern parts of S. America and in Texas. Thence a rather slower spread occurred in the U.S.A., but B was widely prevalent in that country by November. In Europe it did not appear till December—in Holland and Belgium ; the peak in Britain was in January. From the Pacific the virus apparently went also southwards and caused an outbreak in Australia at what is for them an unusual time of year—November. There are two reasons for believing that there was a true spread over the world. First, B strains recovered recently in Australia and Britain are antigenically very closely related and decidedly different from the standard B strain, Lee, isolated in America in 1940. Second, the disease showed rather unusual epidemiological features and those which Burnet has described from Australia are identical with those we have lately seen over here : in both countries the incidence has been very patchy but with a high incidence in schoolchildren and very little in adults, noticeably little in the Army.

One wonders therefore whether the influenza viruses may not be endemic in every country, but at the same time so labile that they easily produce mutant forms sufficiently distinct antigenically from the stock to be able to infect a substantial number of people who are resistant to their endemic strain. Virulence might soon be raised and further extension made possible. Thus a country to country spread could be quite commonly superimposed upon endemic influenza. What has perhaps occurred during the past year with Influenza B may be not unlike the happenings of 1918–1919, except that in contrast to the pandemic virus, last year's antigenic variant of B caused only a mild disease, not readily differentiated from the local endemic influenzas.

We cannot find out whether there is a country to country spread as a normal occurrence unless there is co-operation between countries in collecting and comparing strains from outbreaks ; and I would suggest the desirability of ensuring that in every considerable region within the Empire there are trained observers capable of collecting and comparing strains, or at least collecting and transmitting to centres where detailed comparisons may be made. I suggest that it is possible that what we may call the global epidemiology of influenza may be in a state of transition as a result of the enormous increase in air transport which we are seeing to-day. If so, it is most important for us to be able to observe accurately what is happening.

We need knowledge of these and other matters if we are to be able to combat the fatal type of pandemic influenza should it return. We should like, by quarantine restrictions, to exclude a new and dangerous virus, if only to give time for making a vaccine against it. The pandemic of 1918–1919 did not hit Australia until several months later than most of the world, and I understand that the Australians attribute this temporary freedom to their quarantine restrictions. But I have heard doubts expressed as to whether that quarantine had, in fact, anything to do with the course

of events ; influenza viruses, we now know, are quite frequently carried during epidemics by persons without symptoms, and the Australian quarantine was not, I should have thought, such as to prevent rather free dispersal of virus by such asymptomatic carriers. Possibly the non-pandemic influenza prevalent in Australia in September–October 1918 conferred a temporary resistance. The question is an open one. At any rate it would be very wise for all countries to decide now, without waiting until a pandemic occurs, what quarantine measures are desirable and feasible, in the face of a disease which still has the potentiality of killing people by millions.

Encephalitis

I have a few words to say about the insect-transmitted forms of encephalitis. In North America there exist St Louis encephalitis and the Western and Eastern forms of equine encephalomyelitis, all of which can infect man. They concern mainly the U.S.A. but may and do spread over the border into Canada. The Americans are rightly worried about the dangers of introducing from the Far East the Japanese B encephalitis which is a more serious and fatal malady than the forms of the disease they already have. The appropriate mosquito vectors for the Japanese B virus are well distributed in North America. Here, if needed, is a further argument for strengthening the precautions against accidental carrying of insects in aircraft. Happily, man does not carry these viruses—or not for long—in his blood, so that it is likely that exclusion of mosquitoes will exclude the diseases. What is badly needed for our peace of mind is more knowledge of the ecology of these viruses. Equine encephalitis was first recognized as a disease of horses, later found to cause encephalitis in man, then recovered from infected birds, especially domestic fowls and from wild-caught mosquitoes. It now seems likely that the infection is kept going during the summer in a bird-mosquito-bird cycle, men and horses being only accidentally infected and not serving to propagate the infection. But the natural history of the disease is not yet made plain. We know how the viruses may keep going in the summer but do not understand how they survive the winter. They have not been found to survive in over-wintered mosquitoes nor to be transmitted through the egg to a second generation, nor to persist long in any vertebrates. Recovery of virus from chicken-mites (*Dermanyssus gallinae*) has not yet brought conviction that that species can act as a round-the-year reservoir of infection. One suspects that yet other arthropods or vertebrates remain to be identified as playing a vital part in the infection-cycle. Ecological studies are of great importance in all such insect-transmitted infections ; only by knowing all the necessary conditions for survival of an infective agent can we know when and where to redouble our precautions against spread of infection to new areas and when and where we may safely relax them. In our present state of knowledge the maxim should be ' safety first.'

RICKETTSIAL DISEASES IN THE AUSTRALIAN REGION

By Dr F. M. BURNET, F.R.S.
(Director, Walter and Eliza Hall Institute, Melbourne)

THE position in Australia and the adjacent territories is as follows :—

EPIDEMIC (LOUSE) TYPHUS

This has not been recorded in the present century.

ENDEMIC (MURINE) TYPHUS

Infection is widely distributed but very few cases are reported annually. Foci exist at Fremantle, Port Adelaide and Brisbane, usually associated with rat infested grain stores. An epidemic in Toowoomba (Queensland) was associated with a 'mouse plague' in a country district and a few cases were observed amongst troops in North Queensland during the war years. Diagnosis has usually been made on a basis of agglutination tests with Proteus X 19, but at least two rickettsial strains have been isolated and shown to conform to the type found elsewhere. There has been no adequate local study of the reservoir of infection, but there is no reason to believe that the conditions in the parts where most cases occur differ essentially from conditions elsewhere in the world.

SCRUB TYPHUS (TSUTSUGAMUSHI DISEASE)

This is present in North Queensland, especially around Cairns and the Atherton tableland, throughout the New Guinea territories and probably in most of the adjacent islands including Bougainville and New Georgia in the Solomons. The human disease is to be regarded as a rare incident in the life history of *Rickettsia orientalis* which is essentially a parasite of the Trombiculid mites, *Trombicula fletcheri* and *T. walchi*. The principal hosts of these mites are wild rats, e.g. *Rattus concolor browni*; rickettsia has been isolated from the brains of wild rats of this species. Infection of man is by the bite of larval mites which have been infected trans-ovarially and have crawled up grass stems, etc., after hatching in soil or ground detritus.

Under peace-time conditions the disease is only likely to affect Europeans engaged in clearing scrub land in the areas involved. It can hardly be regarded as an important public health problem but occasions can be visualized, e.g. road or aerodromes construction, where it might be desirable to immunize the labour force concerned.

Q FEVER

This was first observed at a Brisbane abattoir in 1936. Cases have continued to occur there and others have been observed in country areas in South Queensland with one case as far north as Ingham. The accepted life history of the rickettsia is that it is a parasite of ticks especially *Haemaphysalis humerosa* with the dominant host animal the bandicoot, *Isoodon torosus*. The rickettsia can multiply readily in the intestine of several species of tick, including the cattle tick *Boophilus*. Circumstantial evidence strongly favours the conclusion that infection at abattoirs and in dairy farms is due to inhalation of dust containing faeces from infected ticks.

NORTH QUEENSLAND TICK TYPHUS

This is at present underscribed and papers dealing with it will shortly appear. Human infections occurred amongst soldiers carrying out jungle exercises in the Atherton Tableland area in 1944. The rickettsia resembles those of other forms of tick typhus but is serologically distinct. *Ixodes holocyclus* is suspected of being the vector.

In summary all the main varieties of rickettsial disease apart from epidemic typhus occur in the Australian region, but under peace-time conditions none are of serious public health importance. It is desirable that adequate facilities for serological diagnosis of these diseases should be available and the possibility of their occurrence should be kept in mind when any extensive clearing programmes are undertaken in the areas involved. If there is any considerable European development of New Guinea in the future the provision of opportunities for vaccination against scrub typhus will need consideration.

MEDICAL RESEARCH IN THE UNION OF SOUTH AFRICA

By E. H. Cluver, M.A., M.D., D.P.H.
(Director, S.A. Institute for Medical Research)

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1. INSTITUTIONS AT WHICH RESEARCH IS CARRIED OUT

The institutions at which medical research is at present being carried out in South Africa are :

i. The South African Institute for Medical Research in Johannesburg with its branches at Port Elizabeth in the Cape Province and Bloemfontein in the Orange Free State.
ii. The Medical Schools of the Universities of Cape Town, Witwatersrand and Pretoria.
iii. Central, Provincial and Local Government Departments.
iv. Private medical laboratories and other agencies.

The South African Institute for Medical Research

In 1912 the gold mining industry directed the attention of the Union Government to the need for medical investigation in the Transvaal. The outcome of these negotiations was the setting up of the South African Institute for Medical Research in Johannesburg jointly by the Health

Department of the Government and the Witwatersrand Native Labour Association of the Transvaal Chamber of Mines for the purpose of (*a*) carrying out research with a view to the prevention and treatment of human disease and (*b*) providing routine medical laboratory services and the preparation of materials for the prevention and treatment of disease, such as vaccines and sera.

The Institute has increased considerably in size during recent years. It has set up branches in Port Elizabeth, Bloemfontein and at Rietfontein, a farming area immediately north of Johannesburg. At the last named are accommodated the laboratories for the preparation of curative sera and those for the preparation of vaccines against rickettsial diseases, yellow fever and influenza. The staff employed comprise 196 Europeans and 154 Africans.

The research carried out is divided for convenience of administration into (*a*) technological research, (*b*) investigation of local public health and industrial hygiene problems, (*c*) unfettered research. Technological research is concerned with the improvement of routine procedures for diagnosis and the preparation of vaccines, sera and other therapeutic substances. This is adequately provided for by the excess of revenue over expenditure on the work done in the Routine Division of the Institute. Research under the second head is financed from an annual grant of £15,000 contributed in equal parts by the Union Government and the Chamber of Mines. Gifts of money have made possible the appointment of officers to do research other than that provided for under (*a*) and (*b*). The classification outlined can obviously not be rigidly adhered to, but is a convenient guide for the allocation of funds derived from the three sources.

The publications by officers of the Institute are listed in the Annual Report of the Director. They appear in *Publications of the South African Institute for Medical Research* and in technical journals published both in the Union and overseas. They cover a very wide range of subjects, some of which are referred to in subsequent papers.

Medical Schools

Three of the five universities in South Africa have medical schools which provide the full medical curriculum. The oldest is the University of Cape Town which turned out its first medical graduates in 1922. The University of the Witwatersrand, Johannesburg, produced its first medical graduates in 1924. The Medical School of Pretoria University was only recently established. It will turn out its first batch of graduates next year. Postgraduate courses are provided at the Witwatersrand and Cape Town Universities. Because of its close association with the South African Institute for Medical Research the Witwatersrand University is able to cater particularly well for public health and tropical medicine students. In addition to courses leading to the degrees of M.D., Ch.M. and Ch.M. in orthopaedics it provides diploma courses in public health, tropical medicine and hygiene and in psychological medicine. Arrangements are now being made for the provision of diploma courses in forensic medicine, anaesthetics, clinical pathology, radiology, physical medicine and ophthalmology.

The staff of these medical schools, particularly of the pre-clinical departments, have made some noteworthy contributions to medical

research but its amount is entirely disproportionate to the size of the faculties. This must be attributed to the small size of the staff as compared with the very large numbers of medical students ; there were 1,466 on the Register of the South African Medical Council on 31 December 1945. A rapidly increasing number of medical practitioners is registered annually. During 1945 the number was 286. The faculties are very much alive to the need for more research being carried on in the various departments if only for the reason that teaching must deteriorate if the teachers are not actively engaged in research. There is reason to hope that a more liberal Government policy in regard to the financing of universities will tend to lighten the heavy burden of teaching and so allow of more time and facilities for research.

Until recently there was no organized arrangement for clinical research at any of the universities and work was carried out solely by members of the staff in connexion with the investigation of cases under treatment and in connexion with the teaching. At Cape Town a temporary Research Chair in Radiology was established shortly before the outbreak of the war and filled by Professor J. van Roojen. Soon after that the same university appointed a whole-time research worker in the Department of Surgery in the person of Dr R. H. Goetz. Dr Goetz works on the physiology and surgery of the peripheral vascular system. Recognizing the high quality of this work the University of Cape Town last year created a Research Associate Chair for Dr Goetz in the Department of Surgery.

The Medical Graduate Association of the Witwatersrand founded in 1935 the *S.A. Journal of Medical Sciences* which is now financed jointly by the University and the South African Institute for Medical Research.

Government Departments

The Union of South Africa is governed by the Central Government (Senate and House of Assembly), Provincial Administrations and Local Authorities.

The acts establishing various Central Government departments provide for the carrying out of research. Thus the Public Health Act requires the Department of Public Health ' to promote or carry out researches and investigations in connexion with the prevention or treatment of human diseases.' Under this provision the Department makes an annual grant to the South African Institute for Medical Research and itself directly undertakes certain researches, e.g., by inviting scientists of standing from other countries to investigate particular health problems ; malaria and solar radiation are subjects which have been studied in this way. The Department also has on its staff a research ecologist headquartered at the Plague Research Laboratory set up jointly by the Department and the S.A.I.M.R.

The National Advisory Council for Physical Education falls under the Union Education Department. It has an active Medical Research Committee which publishes a bi-annual journal, *Manpower*.

The Union Department of Labour is arranging for the establishment of a National Advisory Council on Industrial Hygiene which is to have research committees on applied physiology, industrial medicine, and industrial psychology.

The wide range of veterinary researches carried out under the Department of Agriculture are dealt with in the papers presented by Dr P. J. du Toit.

Some research is carried out or sponsored by provincial departments. Field research on bilharziasis carried out by the Transvaal Education Department and nutrition surveys conducted by all four provincial education departments are examples.

Of the local governments only the larger municipalities have provided for any medical research, usually short term investigations of local problems.

2. NUTRITION

Africa offers unusual problems to the student of nutrition. The co-existence of two widely separated stages of human development presents modes of nutrition which are in sharp contrast with each other. At the one extreme is the African tribal diet, based almost entirely on cereals and supplemented by a host of ' unconsidered ' trifles whose value—not to say necessity—is now only beginning to be recognized. At the other extreme is the diet of the civilized African city dweller, essentially similar to that of the Europeans. Between these two extremes are the transitional stages in which the traditional tribal foods and beverages are discarded before the attractions of refined cereals, sugar, tea, highly coloured drinks and all other gastronomical sophistications of civilization. It is during this interim period of development that dietery imbalance, malnutrition, deficiency disease and poverty form a vicious circle which is difficult to break by means of purely remedial and therapeutic measures.

This does not mean that malnutrition is not present in less civilized areas—it is rife throughout Africa. Tropical diseases of all kinds can also be found in almost all parts of the continent. In consequence the aetiology of African nutritional disease is complex and its elucidation very much a thing of the future. It is not only further advances in fundamental knowledge that are necessary. A more intensive study must be made of the *application* of such theory to conditions among the different areas and races of Africa.

Survey of Vitamins in African Foodstuffs

A beginning has been made in the investigation of the nutritional changes which come about as a result of civilizing influences and during migration from rural to urban areas. This has necessitated a systematic quantitative survey of the common ingredients of the African tribal diet. Preliminary work has been concerned mainly with the vitamin content of foods which are of basic importance in the diets of Europeans and Africans. The main groups of foodstuffs studied so far have been : cereals, legumes, fermented foods, edible wild plants, common vegetables, infant foods and human milk of Bantu mothers.

The vitamin A and D contents of South African fish oils have been the subject of detailed investigation in Cape Town. Parallel experiments on the antirachitic value of South African sunshine have also been reported.

Cape Nutrition Survey

The Union Health Department of South Africa provided funds for a nutrition survey in the Cape Peninsula. The primary objective of the work was to establish reliable criteria for the recognition of human malnutrition and to attempt to define the borderline between normal nutrition and sub-nutrition.

Studies of Mineral Metabolism

The exigencies of war have thrust upon South Africa a whole-wheat 'standard' bread. In view of the nutritional repercussions which may have attended the use of this bread, mineral metabolism in human subjects has been studied, using extended balance periods and measuring the absorption of calcium, magnesium, iron and phosphorus from bread.

The influence of dietary and other factors upon the formation of teeth in rickets and the action of fluorine on tooth formation have been studied in some detail.

Research Employing unusual Experimental Animals

The wealth of African fauna is well known. Among these animals there are many which offer opportunities for the investigation of biochemical and physiological problems from a fresh point of view. In this way there may be added to the list of common laboratory animals new species with new potentialities. Two examples will suffice. The development of the South African amphibian *Xenopus laevis* as a test animal for the diagnosis of pregnancy has gained world-wide recognition. Research on the nutrition of the larva of the mosquito *Aedes aegypti* has thrown light on a number of problems which have a considerable bearing on human nutrition.

Suggestions for Future Research

The co-ordination of nutritional research in Africa, so often decided upon at past conferences, and delayed by the war, must now be brought into effect. The need for research is unique both from point of view of urgency and also because of the potential value of such investigations to the progress of nutritional science as a whole.

Extension of the research now in progress is essential but much more than this is envisaged. Work on vitamin and protein deficiency and imbalance must be allied to climatological studies in areas with widely different environments. Studies of the reciprocal influence of tropical disease and malnutrition on each other have high priority and demand concerted action by all African governments. Existing knowledge should be applied in the form of remedial and preventive measures whose effects will need careful assessment.

It is essential that we train a body of nutritional research scientists, adequate both in ability and numbers to grapple with the vast unexplored problems which lie before us.

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3. MANPOWER

In 1938 the Hon. Mr J. H. Hofmeyr, in his capacity as Minister of Education, accepted the recommendations made in a technical memorandum submitted to him by the South African Olympic and British Empire Games Council to the effect that a National Advisory Council for Physical Education be appointed. Most of the problems with which this Council was confronted immediately after its formation were of a medical nature, and since these problems demanded the undertaking of research, a committee was formed for the purpose. The term ' Manpower Research ' has been adopted as to our knowledge no other name had so far been accepted for this type of work. The scope of the research undertaken by this Committee is indicated in a report which the Advisory Council has just recently issued in its journal, *Manpower*. Copies of this are available. I shall therefore confine myself to a brief summary of such investigations as have been completed.

The increasingly large numbers of physically, socially and economically sub-standard Europeans in South Africa, usually referred to as ' poor whites,' led to the appointment in 1928 by the Government of a Commission of Investigation which, with the generous financial assistance of the Carnegie Corporation submitted in 1929 a comprehensive report. To a small group of medical research workers, this report suggested that the ' poor white problem ' was the result almost entirely of environmental circumstances, such as malnutrition and lack of education, illness and unsatisfactory housing conditions, a concept which at that time was not accepted in South Africa. However, on scientific grounds the thesis was put forward that ' poor whites ' could be rehabilitated; and that sufficient knowledge was available of measures that could counteract the deteriorating effect of the disabilities which were prevalent among the under-privileged people concerned.

In 1936 a large educational camp for ' poor white ' youths was opened at Roberts Heights, the main training centre of the Union Defence Force. The effect of the carefully chosen camp environment upon the young men was studied by a team of research workers. The success which followed the application of this then new concept of rehabilitation represents one of the most gratifying results of research in South Africa. A number of reports on this investigation have been prepared, copies of which are available to delegates. It will be noticed that the premises on which this experiment was based proved to be correct. A concerted effort to apply educational, medical, nutritional, athletic, cultural, spiritual and disciplinary methods were equally successful with white (European), ' Cape Coloured ' (Eurafrican) and black (Bantu) youths. From unhappy, unhealthy, undisciplined and altogether unemployable human material there emerged contented, dignified and industrious citizens able to manage their own affairs. Many of the young men who were among the first batch

of pupils of the camp at Roberts Heights subsequently distinguished themselves in the war, some of them as officers. Less than 10 per cent of all youths who came to the camp school failed to react to the rehabilitative effort.

The Government of the Union of South Africa has greatly facilitated this work ; various monetary grants were made for the purpose either directly through the National Advisory Council for Physical Education or indirectly through the Union Defence Force, the South African Institute for Medical Research, the University of Stellenbosch and the Witwatersrand Technical College. During the war, the Department of Defence in collaboration with the Departments of Social Welfare, Labour and Education established a number of model camp schools for such Army volunteers as had to be rejected because of physical defects. Since the majority of the defects were found to be of a remediable nature, these volunteers instead of being sent back home, were admitted to special centres in which they not only received medical treatment but where they also enjoyed the benefits of an elaborate system of educational, cultural and disciplinary guidance. The entire scheme which has now been placed under the control of the Minister of Education, is the result of the comprehensive research concept to which I have referred. We are continuing to collect data at the camp schools. These data are analysed, and interpreted with a view to submitting from time to time recommendations to the authorities concerned. Satisfactory collaboration has been established in this matter between our research teams and the administrative officials.

A second line of research with which we have been concerned for some years is the physiological inter-relations between diet and physical efficiency. Part of this research work was dealt with in my paper on nutrition. In the present summary I shall confine myself to a reference to several comprehensive studies that were undertaken on the extent to which growth and physical efficiency were affected by such manifestations of ill-health as were known to be of dietary origin. The results of this survey were published in *Manpower*.

In another research project the developmental, medical, scholastic, physical and nutritional status of school children six to seven years of age were correlated. This too is described in the Council's report. Then we have studied the effects of certain dietary habits of a religious origin such as the Ramadan Fast of Mohammedan Indians in South Africa. You will find a summary of these researches also in *Manpower*, March 1946.

A third major research project aimed at the collection of information on the inherent labour potential of the Bantu population of South Africa. It must be borne in mind that the great majority of inhabitants of South Africa and of the British Protectorates in Southern Africa belong to the black-skinned races. Most of them have never participated in industrial or agricultural production in a manner and to an extent comparable with even minimum standards of Western European communities. This in addition to the educational, social and physical handicaps with which many of them are burdened, has rendered it difficult to assess their inherent labour potential, and we could not judge their ability to become integrated into a progressive pattern of production in any modern scheme of agricul-

tural and industrial developments. We have therefore made a determined effort to throw light on this question.

Several accounts of the researches in this direction have been presented. I shall therefore confine myself to a repetition of statements previously made to the effect that the black-skinned races appear to be better fitted to perform physical work than are members of the white and of other races. The black man's superiority in physiological adjustment to effort is particularly striking under conditions in which the body's capacity to regulate its temperature is strained. The black man stands atmospheric heat better than the white man. The practical implications of this finding which have been corroborated are, of course, far reaching. Thus you know that the gold mining industry in South Africa is at present concerned with plans to extend their operations in depth. A recent Government report by a commission of experts under the chairmanship of Sir Robert Kotze which investigated the future of deep-level mining has referred in detail to the above-mentioned physiological researches.

Fourthly, brief reference must be made to certain physiological and clinical studies pertaining to competitive sports. It is recognized that a nation's athletic achievements are correlated with its general physical, social and economic status and that for this reason alone it would be imperative to pay attention to the maintenance or development of a high standard of athletic performances. Other aspects of this problem were discussed at length in a paper on Recreation, published in *Manpower*, September 1943.

Fifthly, some of our clinical studies of athletes afflicted with illnesses may be summarized. In particular we have analysed in South Africa the interesting inter-relationship between cardiovascular illness and physical efficiency. The main conclusion reached in these researches is that the old clinical concept that the presence of pathological conditions necessarily indicates a reduction or even a breakdown of the physical action capacity of the patient must be altogether revised. This result was arrived at before the war ; the practical significance of the new point of view was considerably enhanced during the ensuing years. The findings have since been repeatedly corroborated.

Finally, I must refer to a number of comprehensive medical theories which have emanated from the results of our studies. They have been summarized in the general account of our researches given in the last number of *Manpower*. In this publication bibliographic references are given to the original publications. These theories have made it possible for us to travel in a land which hitherto has been a *terra incognita* of medicine.

It is pleasing to record that we have received the most valuable advice and collaboration from research workers in the field under review in Great Britain, the Dominions and elsewhere. We have also succeeded in establishing contact with many of the leading centres of medical research in manpower and physical education in the Empire. As I have indicated, the Government of the Union has generously placed at our disposal a scientific journal in which we can publish the results of research work undertaken by the National Advisory Council for Physical Education. In this journal we have repeatedly had the privilege of presenting papers written by scientists who work outside South Africa. Thus the September

1946 issue of *Manpower* will be devoted entirely to a review of the magnificent physiological researches of Professor Selye of McGill University, Montreal, Canada, whose investigations have contributed so much to our understanding of the nature of the adjustment of the animal organism to exercise and to a variety of other physiological strains.

There can be no doubt as to the importance of research on manpower and physical education. In 1943 a representative Board was formed in Great Britain to co-ordinate research in medicine and physical education. This Board which has already issued a number of valuable reports is the counterpart of the Medical Research Committee of the National Advisory Council for Physical Education in South Africa. Contacts between these two bodies have already been established ; it is unnecessary to say that it is our intention to foster and develop these contacts. I am aware of the fact that efforts are afoot to consolidate medical research in physical education throughout the Empire. I therefore feel that the time has arrived to create the necessary facilities for scientific intercourse and exchange of views between Government research workers in this field. I suggest that the British, Dominion and other Empire Government authorities concerned should :

(i) allocate the responsibility for medical research in physical education to suitable bodies so that the necessary contacts may be established throughout the Empire ;
(ii) provide appropriate grants and facilities for manpower research ;
(iii) endeavour to establish within their respective administrative regions contacts between manpower research officers and research organization in education, industrial hygiene and sociology.
(iv) undertake to furnish at regular intervals official reports of such research work as has been completed.
(v) arrange from time to time scientific meetings or conferences of their manpower research officers, where joint programmes for co-ordinated studies can be considered. These might appropriately be held in connexion with the British Empire Games, provided the Games are held at intervals of not longer than four years.

4. BIOCLIMATOLOGY

Miss G. Riemerschmid of the Jena Institute of Physical Therapeutics was invited to the Union in 1937 to undertake a systematic sunlight survey by setting up stations in various parts of the country. This systematic work had to be discontinued on the outbreak of hostilities. Miss Riemerschmid's services were, however, retained and the following is an account of her work during the past eight years on the quantity and quality of South African sunlight and its influence on biological reactions.

Collection of Basic Data

Solar Radiation. The intensity and the total amount of the radiation from the sun and the sky obtained at various localities of the Union of

South Africa were determined for the period of one year at six stations, and for the period of five years at four stations.

These data form the basis of bioclimatological research with regard to human beings, plants and animals. Furthermore they allow a comparison of the European and South African radiation climate. They were used to compare the amounts of radiation influencing cattle under European and South African conditions, including a study on the absorption of solar radiation in hides of different colours.

Cooling-ball Temperatures. Cooling-ball temperatures represent the combined influence of air temperature, wind velocity and radiation on a resting naked human being. Although these readings are strictly speaking only applicable to human beings, they nevertheless give valuable information on the climatic conditions generally. The data obtained from six stations during one complete year were used for a comparison of climatic conditions in regard to the therapeutic value of South Africa's climate with those of Europe.

Ultraviolet intensities of the solar radiation. These were determined by S. J. Richards.

Biological Influence of Solar Radiation

Hitherto little proof of any direct influence of the sun's rays on animals has been forthcoming. Healthy animals appear to possess great adaptability to exposure to sunlight. In sick animals, on the other hand, the adaptation may be reduced and direct reactions may result.

Miss Riemerschmid and Dr W. O. Neitz were able to prove a distinct and direct influence of the solar radiation on sheep suffering from a virus disease (blue-tongue). In exposed sheep the clinical symptoms and pathological changes were much more pronounced and the convalescent period much longer than in those protected against sunlight. The removal of the protective layer of wool by shearing enhanced the detrimental influence of solar radiation considerably.

An outstanding feature of the post-mortem examination was the observation of intramuscular and subcutaneous haemorrhages, particularly under the shorn areas of the fleece. Studies on this specific influence of solar radiation may lead to proof of a direct influence of sunlight on human beings. Experiments can, however, only be carried out on animals and under climatic conditions which permit continuous exposure for an uninterrupted period of many days. South African climate seems particularly suitable for such research.

The studies of the influence of the ultraviolet component of the sun's rays on various virus diseases are of particular interest because of the fact that the natural light of the sun is distinctly different from that emitted by the artificial sources used in countries less favoured than South Africa with sunshine. It was possible to repeat experiments under exactly similar conditions of exposure over periods of many weeks and to limit the duration of exposure necessary to obtain a certain result to a very narrow range.

The correlation of physiological and biological effects with one or other meteorological factor or with solar radiation alone is not enough. Only the study of the complex quantity climate' and the simultaneous

influences of its various components can lead to a true understanding. Statistical analysis of observations with the ultimate aim of placing bioclimatological research on a quantitative basis were carried out by Miss Riemerschmid in collaboration with the statistician D. v. d. Reyden. It seems essential, however, that new methods of measuring the environmental influences should be developed. Meteorological data represent the climate in units which have primarily a physical significance. One of the most important tasks of bioclimatological research is the development of methods by which meteorological factors could be measured in such a way that the measurements have a physiological significance ; in other words the methods should integrate various meteorological factors in a similar way to their *combined* effect on plants and animal or human bodies. Ultimately such measures may facilitate a sensible correlation between meteorological factors and physiological processes.

The provision of reliable data on solar radiation should form the basis of studies on diseases in man, such as pellagra, rickets, arterial sclerosis, etc. Data on the regional variation of intensity and quality of solar radiation collected by the Solar Radiation Survey have been provided to scientists interested in the study of such diseases. It is felt that a better correlation between the work of the medical and physical research workers is required to enable a programme of observations on solar radiation to be planned in advance to meet the requirements of special information with regard to special problems.

Solar Radiation Hygiene

The data already available make it possible to give advice to the public on the beneficial influence of solar radiation in preventing and treating disease and on the harmful effects of over-exposure. A campaign for the sensible use of sunlight is indicated. But it is essential that the information supplied be based on facts established by a combined medical and physical approach to the subject.

Copies of the publications of Miss Riemerschmid and her associates are available to delegates.

Altitude

Dr H. I. Lurie of the Institute for Medical Research has determined the normal haematological standards for adults living on the Witwatersrand at an altitude of 5,740 feet. These have been compared with normal standards at sea-level.

The conclusions arrived at were as follows :

(i) The number of red cells and haemoglobin content of the blood is higher than at sea-level.
(ii) Each red cell contains as much as or slightly more haemoglobin than does a red cell at sea-level.
(iii) The volume of each red cell is slightly larger at this altitude.

Investigations in similar lines were previously carried out by Dr Buchanan, Mr Emmerson and Mr Symons of this Institute, and by Professor Stammers and Mr Garanovsky of the Medical School.

One of our staff (Mr Emmerson) also investigated the effect of underground work on the erythrocyte count of Europeans working on the Rand Gold Mines. He found that there was a tendency for the red cell count to decrease as the depth of working increased.

There still remains to be investigated the normal standards for infants and children at this altitude. It still has to be proved that the Normal Values for the Bantu are the same as for Europeans.

5. THE PNEUMONOKONIOSES

Medical (as opposed to ' engineering ') research into silicosis in South Africa proceeded along certain specific lines, which included chiefly clinical, radiological, pathological, chemical and experimental investigations.

The earliest work consisted of observations of clinical signs and symptoms of silicosis with descriptions of the gross pathological anatomy, cause of death and the expectation of life (cf. papers by W. Watkins Pitchford and L. G. Irvine and collaborators). These papers indicated that the type of silicosis then seen was associated with infective massive fibrosis and gross emphysema. Life was of short duration once the disease was contracted and the cause of death was commonly a cardiac one due to right-sided heart failure.

It was considered as a result of these early researches that the concentration of a particular type of dust produced by some mining operations, such as drilling and blasting, was the direct causal factor and that possibly the presence of noxious fumes produced during blasting operations was an additional contributing factor to the production of the disease.

The high mortality among miners of the Witwatersrand at this time resulted in the establishment of improved working conditions, particularly in relation to the reduction of dust by dust-laying methods and in the removal of noxious fumes by improved ventilation. A change for the better was now observed in the clinical and pathological manifestations of the disease.

From 1916 onwards, following on new government regulations, better control and the selection of a special type of individual in regard to general health and chest measurement, the disease was found to develop more slowly ; fifteen years was now the average period that elapsed before the first detectable signs appeared. It was also found to be much less severe in type.

This information is recorded in the reports of the Miners' Phthisis Medical Bureau for the years 1927–1938.

Investigation into the Correlation of Clinical, Radiological and Pathological Manifestations

Later a controlled investigation was carried out by correlating clinical, pathological and radiological manifestations in a specially selected group of six hundred individuals. *Post-mortem* examinations were carried out on subjects who had died as a result of accident or from diseases other than silicosis. Among these were miners with varying periods of service ranging from a few months to many years. The correlation of the radiological

picture with the pathological condition was made in cases in which death had taken place within one month of the last radiograph taken. This work is recorded in the papers 'Silicosis in South Africa, 1930' and in papers presented to the Silicosis Conference, Johannesburg, 1930.

In addition to the above data derived from the examination of the special group of six hundred cases, clinical and pathological correlation with radiographs was carried out in the course of routine work. The amount of material available is indicated by the fact that there were at that time forty thousand European miners, each of whom was subjected to an initial examination (which included a radiographic picture of the chest) and to a similar periodical examination every six months thereafter during the whole term of his mining life.

In many instances there was periodical radiographs of particular individuals over periods of 20–30 years. This wealth of material provided ample opportunity for research along the lines indicated above. On the pathological side, if a miner dies, the lungs and heart are forwarded to the Miners' Phthisis Medical Bureau for examination by the pathologist. The number of deceased miners with complete industrial histories and with the results of clinical and radiological periodic examination on whom post-mortems have been performed amounts on the average to four hundred and fifty per year. In addition to these, the lungs of an equal number of combined non-European and African deceased miners have been similarly dealt with. Over a period of twenty years, 18,000 pairs of lungs from Witwatersrand miners have been examined ; this has provided a wealth of material for correlating the clinical, pathological and radiological conditions.

Research into the Pathology of Silicosis and its Complications

This material has also afforded an opportunity for investigating the incidence of cancer in silicotics and non-silicotics and particularly to compare such incidence with cancer in the non-mining population. This material too has provided an opportunity for studying the pathogenesis of silicosis from the initiation of the process through all intermediate stages to the most marked manifestations of the disease together with all complications which may arise in connexion with it. It has been possible in this way to examine the lungs of miners who have been exposed to the effects of silica dust for periods of a few months up to periods of 20 years or more.

The results of this work have been incorporated in the following papers :

Publ. S. Afr. Inst. med. Res., **15**, 1922
Publ. S. Afr. Inst. med. Res., **19**, 1926
Mine Med. Officers' Ass. J., Oct. 1930
Papers presented to Silicosis Conference, 1930
Publ. of S. Afr. Inst. med. Res., **36**, 1935
J. Path. Bact., **11**, 1935.

Relationship of Tuberculosis Infection to Silicosis

The problem of the relationship of tuberculosis to silicosis has also been investigated both from the clinical and pathological points of view, the latter including experimental investigation of silicotic fibrosis material from human cases injected nto susceptible animals for determining the

presence or absence ot living tubercle bacilli. This was done especially with the type of lesion known as tuberculo-silicosis, in which the only stigma of tuberculosis was necrosis (*Publ. of S. Afr. Inst. med. Res.*, **36**, 1935).

The record of all experimental work in relation to tuberculosis is recorded in the following papers :

Publ. S. Afr. Inst. med. Res., **15**, 1922
" " " **19**, 1926
" " " **30**, 1932
" " " **36**, 1935.

Silica as the Active Agent in the Production of Silicosis

Up to the year 1932, silica was regarded as the most active agent in the production of silicosis. In 1932, however, W. R .Jones, of the London School of Mines, suggested that the silicate sericite might be the chief cause.

Investigations into the physical and chemical characters of dust extracted from the lungs of Rand miners were carried out in 1913 and 1916 (*Publ. S. Afr. Inst. med. Res.*, **1**, 1913, and **7**, 1916), and subsequent to Jones' expression of opinion concerning sericite, further chemical investigations were conducted, the details of which are recorded in :

S. Afr. J. med. Sci., **2**, 1937
J. Path. Bact., **44**, 1937
Publ. S. Afr. Inst. med. Res., **45**, 1940.

For many years there has been a doubt as to whether silicotic fibrotic lesions were the direct effect of the action of silica particles or whether the lesions were manifestations of an infective process from the outset. On the experimental side inhalation methods of producing silicosis could not be dissociated from infection, therefore the injection method was preferred in some of the later experiments. In injection experiments there was the advantage that the dust could be properly sterilized in addition to the range of particle size and the dosage being adequately controlled. In experiments recorded in the *J. Path. Bact.*, **44**, 1937, and *Publ. S. Afr. Inst. med. Res.*, **45**, 1940, these conditions were observed.

The injection method of experiment definitely proved that silica could cause fibrosis in the absence of infection. An attempt was also made to correlate the effect of the amount and type of dust in the naturally acquired disease and also that which had been introduced experimentally into animals with the specific lesion caused by its presence.

Investigations on the experimental side included inhalation experiments and experiments in which dust in suspension was injected into the circulation, peritoneal cavity and into subcutaneous tissues of animals. Various types of mineral dust were used, including rutile, mine dust, pure quartz, glass, coal and various silicates. The results of these animal experiments are recorded in :

Publ. S. Afr. Inst. med. Res., **15**, 1922
Publ. S. Afr. Inst. med. Res., **19**, 1926
J. Path. Bact., **44**, 1937
Publ. S. Afr. Inst. med. Res., **45**, 1940.

As a result of the experimental work carried out here and in other countries, the view is now held that silicosis is caused only by silica (SiO_2).

Chemical Analyses

Chemical analyses of dust recovered from the lungs of miners of the Witwatersrand by a process of ashing or digesting the lung tissue have been carried out and the results are recorded in the following papers :

J. Path. Bact., **44**, 1937
S. Afr. J. med. Sci. **2**, 1937
Publ. S. Afr. Inst. med. Res., **45**, 1940

Histology and Histopathology

A study of the microscopic anatomy of the human lung has been carried out with special reference to potential sites of lymphoid tissue and in order to demonstrate that presilicotic lesions and early silicotic islets are localized in specific situations. These investigations are recorded in papers in :

Publ. S. Afr. Inst. med. Res., **36**, 1931
J. Path. Bact. **40**, 1935.

Silicosis outside the Union

Investigations into the correlation between radiological, clinical and pathological manifestations of silicosis have been carried out on material provided by the mines of the Gold Coast, Kolar Gold Fields, and the mines of Northern and Southern Rhodesia, and have been recorded in reports to the mining companies concerned by L. G. Irvine and F. W. Simson, and by L. G. Irvine.

Sidero-silicosis

The occurrence of silicosis among workers in the haematite mines of Northern Transvaal (Thabazimbi) has also been investigated and the findings are comparable to those reported as occurring in miners working in the Cumberland mines of Britain (cf. *Reports to Miners' Phthisis Medical Bureau*). The lungs of experimental animals kept in the underground working of the Thabazimbi mine have also been examined (Simson) and the results have been reported officially.

Asbestosis

Changes in the lungs of deceased subjects who have been engaged in mining asbestos, or who have worked in mills where asbestos is processed, have been investigated and the liability to tuberculous infection and the difference of the lesions from silicosis have been noted and recorded in the *B.M.J.*, May 1928, and in reports to the Miners' Phthisis Medical Bureau.

Examinations for the presence or absence of asbestos bodies in sputum from a series of subjects who had worked in an asbestos mill were undertaken and the results were recorded in a paper published in *J. Path. Bact.*, **34**, 1931.

Aluminium and Silicosis

When attention was drawn to the claim that aluminium could be used as a prophylactic agent against the development of silicosis, an investigation into the action of aluminium in this respect was conducted (Simson and

Barnetson). The intravenous injection method was adopted but with little success. It was found that sterilization of suspensions in water of the particular aluminium dust at our disposal rapidly caused an alteration in the constitution of the metal rendering it either inert or toxic. The progress of these experiments is recorded in the annual report of the S.A.I.M.R., year ending 31 December 1940.

It is suggested that further experiments be carried out either with the Canadian sample of aluminium dust or preferably with the hydrated aluminium dust recommended by L.U.Gardner, using the long-term inhalation method of experiment.

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6. PNEUMONIA AMONG AFRICAN MINE LABOURERS

Research on the medical control of lobar pneumonia among the African mine labourers of the Witwatersrand goldfields commenced in 1911 when Sir Almroth Wright visited the Transvaal. As a result of the investigations carried out by him and his co-workers mass inoculations were carried out prophylactically with a pneumococcus vaccine.

The pneumonia mortality rate prior to that time was more than 40 per 1000 per annum. Numerous *ad hoc* methods had been devised to reduce the high incidence and death rates from this disease ; these included special diets, suitable clothing, bathing facilities, periods of light work for the initial acclimatization of labourers and the introduction of covered ways between certain parts of the mine and working places. With the stringent enforcement of these protective measures a marked drop in the mortality rates began to show itself about the middle of 1911 ; by the end of that year the then unprecedently low figure of 27·1 per 1000 per annum was reached. It was still, however, a deplorably high figure and it was decided to attempt to improve matters by methods of specific immunization.

At this time some 10 per cent of the African mining population consisted of ' tropicals ' (i.e. those recruited from north of latitude 22° S.). It was well known then, and has since been frequently confirmed, that ' tropical ' boys were very highly susceptible to pneumonia. It was on this account,

indeed, that further employment of such Africans was prohibited by the Government in May 1913.

The work of Sir Almroth Wright and his colleagues related to mass inoculation experiments carried out on various mines chiefly in regard to ' tropical ' Africans. These consisted of field trials in the use of a pneumococcus vaccine prepared from pneumococci recovered from local cases of primary pneumococcus lobar pneumonia which constituted more than 70 per cent of the African cases of acute respiratory diseases. There is no question of the great value of the work of Sir Almroth. The initiation of immunological studies on a large scale proved an inspiration to workers on similar lines not only in this country but also in other parts of the world.

A certain measure of success attended these mass experiments ; but the drop in the pneumonia incidence and mortality rates was not striking. In retrospect, however, this was not surprising. In those days the pneumococcus was regarded as a single organism. The knowledge that it existed as specific immunological entities in the form of various ' types ' was yet to come. Nevertheless, the work done was a beacon pointing the way to future work on large-scale immunization of populations.

In 1913 General W. C. Gorgas arrived on the Witwatersrand at the invitation of the Transvaal Chamber of Mines to investigate the pneumonia problem. His work was more general in nature and had no reference to the question of vaccine prophylaxis of pneumonia, although he recommended that this mode of protection deserved further inquiry.

In 1913 Sir Spencer Lister carrying out his researches on the pneumococcus succeeded in establishing the existence of the various types. Simultaneously, and independently, American workers had reached the same conclusions. The importance of Lister's work, apart from its academic interest, lay in the fact that specific vaccine could now be prepared scientifically corresponding precisely to the various types of the pneumococci prevailing as current infecting organisms. Commencing in 1917 he conducted large-scale experiments on a number of mines with a polyvalent pneumococcus vaccine. The results were regarded as satisfactory both by the South African Institute for Medical Research and by the medical officers in charge of the mines where the experiments were made. Immunization was then carried out on most of the African mine labourers with a resulting mortality rate far lower than had occurred in the six preceding years.

The 1918 influenza pandemic, with its high death rate from respiratory diseases, confused the clear-cut issue of the experiment in pneumococcus vaccine prophylaxis against primary lobar pneumonia because of the deaths that occurred simultaneously from broncho-pneumonia and influenzal pneumonia. These forms of pneumonia continued to be prevalent in subsequent years. The epidemiology of African mine pneumonia had indeed undergone a change. In the pre-pandemic period most of the cases were acute primary lobar pneumonia due to certain limited pneumococcus types. But now, new pneumococcus types and other respiratory organisms appeared in cases of pneumonia. Nevertheless the prophylactic value of the vaccine in use at the time apparently continued to be satisfactory in that the old-time high mortality rate had disappeared ; indeed,

the very low death rate of 1·68 per 1000 per annum was recorded in 1922 for primary lobar pneumonia.

Towards the end of 1926 and in 1927, however, reports began to come in that the pneumococcus vaccine hitherto regarded as a successful prophylactic agent was no longer maintaining its efficacy. From that time onward, Dr Ordman in collaboration with Sir Spencer Lister investigated the bacteriology and epidemiology of pneumonia on the Witwatersrand. They found that the recovery of a pure culture of a pneumococcus in cases of pneumonia was now the exception rather than the rule. The streptococcus, *Haemophilus influenzae*, the *Staphylococcus aureus* and other respiratory organisms were appearing in specimens of lung juice removed from the consolidated lung in patients or from lungs studied at autopsy. Pathologically, too, a change was found to have occurred. The one-time massively consolidated lung was giving place to a less massive lung, more wet and congested. It soon became clear that the pure pneumococcus vaccine in use could no longer be expected to exercise its immunizing value against forms of pneumonia associated with other respiratory organisms. Ordman then prepared a new vaccine comprising not only the important prevalent types of the pneumococcus but incorporating also the other respiratory organisms now found in addition to or in the absence of the pneumococcus.

Further mass inoculation experiments were carried out on various mines with the new vaccine. On one of the mines where inoculations were carefully supervized, the mortality rate fell to 1·5 per 1000 per annum. The immunological value of such a mixed respiratory organism vaccine could not be controlled with that laboratory accuracy that was possible with a pure pneumococcus vaccine. There is admittedly a difference of opinion with regard to the value of the vaccine in pneumonia prophylaxis ; but it has nevertheless consistently been and still is used by the medical officers of certain mines.

In the latter part of 1938 a new phase appeared in the pneumonia problem for that period saw the introduction into therapeutics of the sulphonamide drugs with their dramatic curative value in pneumonia. An average mortality rate from all forms of pneumonia of just over 3 per 1000 per annum on the mines gave place from 1939 onwards to the remarkably low figure of 0·6 per 1000 per annum ; even lower in subsequent years. Interest in the prophylactic aspect of pneumonia by vaccine methods naturally waned when pneumonia once ' the captain of the men of death ' became associated with an almost negligible death rate. Even the highly susceptible ' tropical ' boys were readily cured of pneumonia by drug treatment and their large scale re-introduction to the Witwatersrand mine African labour population speedily followed.

Serum therapy of pneumonia which also for many years had been the subject of research also received a set-back in the face of the ease of treatment by the sulphonamide drugs.

In more recent years penicillin has come in as a most potent weapon in the therapy of pneumonia and has still further forced into the background the need for immunological methods in the control of pneumonia mortality.

Drug or penicillin treatment relates to the cure of established cases of pneumonia and has no reference to the prevention of the occurrence of

that disease. Hence the perfection of a more efficacious prophylactic vaccine is still a desideratum. It is along these lines that future work is directed at the South African Institute for Medical Research.

Research work in pneumonia is being continued in the epidemiology of the disease as well as into the distribution of the pneumococcus types, both in cases of pneumonia and in other pneumococcus infections. Studies have also included investigations into the most effective use of drugs and were carried out particularly in the earlier days of drug therapy when the knowledge of the drugs and their effects was yet in its infancy.

Future research in South Africa demands a control on the bacteriology of the disease to anticipate any possible epidemiological changes that may occur. Further respiratory organisms etiologically associated with pneumonia which may prove to be drug or penicillin resistant should be studied. The question of a virus factor in local cases should also be investigated. The bacteriology of local pneumonia should be constantly under observation with a view to improving the prophylactic vaccine and to continuing that unique bacteriological and epidemiological record of pneumonia that has been maintained for some thirty-five years.

7. TYPHOID ENDOTOXOID IMMUNIZATION ON THE WITWATERSRAND GOLD MINES

After preliminary studies by Dr E. Grasset (who joined the staff of the South African Institute for Medical Research in 1928) typhoid endotoxoid immunization was introduced in the Rand Mines at the end of 1933. Last year Dr Grasset published a statistical examination of the results of ten years of this form of immunization on the Witwatersrand Mines. It is only necessary to give a summary of this paper (Statistical results of ten years of typhoid endotoxoid immunization on the Witwatersrand Gold Mines, *S. Afr. Inst. med. Res.*, 1945, **9**, 163), copies of which are available to delegates.

Previous to the introduction of this form of vaccination there had been high typhoid morbidity and mortality in the mines. During the ten-year period reviewed more than two million African labourers were inoculated. There was persistent evidence of the advantages of the very mild type and low rate of vaccinal reaction. The dramatic fall in incidence and mortality rates in the mines with inoculated populations and the persisting low levels in subsequent years are shown in graphs.

During the ten years of immunization the typhoid incidence, calculated on the total mine African labour complement, fell from 2·78 to 0·13 per 1000 and the typhoid mortality from 0·63 to 0·03.

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8. PLAGUE

Plague was unknown in South Africa prior to 1899. During the following five years several outbreaks occurred, mainly at the ports and at a few inland centres situated along transport routes. These epidemics were associated with rats. Since these sporadic epidemics have continued to occur mainly in association with other field rodents.

The first bacteriological research on plague side was done by Watkins-Pitchford on the outbreak in Natal in 1902–1903. He repeated work of other bacteriologists and did some original observations on the cultural and morphological characteristics of *P. pestis*. The marked pleomorphism of *P. pestis* under various conditions of growth were well and lucidly illustrated. In addition he did controlled experiments on the survival of infection in granaries and store-houses. He found that a specially built house remained infective for one month after all the rats in it had died of plague. He was in favour of the theory that the rat flea played a part in the transmission of plague. Damp soil inoculated with cultures of *P. pestis*, remained infective for one month. In further experiments he showed that the plague organism was susceptible to the influence of direct sunlight, no organism surviving after one hour exposure. He failed to confirm the work of Simpson in Hong Kong in that he could not infect sheep, fowls and pigs with *P. pestis*.

Apart from some reports on the epidemiology of plague there is no trace of systematic laboratory research work on plague until 1926. After 1905 the epidemiology changed and following on field and ecological research by Austin Roberts and others, it was established in 1921 that gerbils were a reservoir of plague and that the sporadic outbreaks since 1914 had been associated with epizootics amongst the gerbils.

In the period 1905–1926 epidemiological observations on plague were made by Mitchell, Pakes, Hayden and others. The rôle of the flea in the transmission of the disease was definitely established in 1911 by the Indian Plague Commission.

In 1926 on the recommendation of Mitchell a systematic research was conducted to elucidate bacteriological, entomological and epidemiological problems connected with plague in South Africa, by a team of workers consisting of Pirie, Ingram and Mitchell.

Pirie found that all rodents likely to be associated with plague were highly susceptible with the exception of *Desmodillus auricularis*. Of the carnivores *Suricata suricatta* was found to be susceptible but *Cynictis penicillata* resisted large doses of *P. pestis*. *Tatera brantsi* was readily infected by feeding (cannibalism).

As a result of field studies he concluded that plague did not become extinct in a previously infected area but merely inactive. Plague infection can be kept active in a scanty rodent population by flea transmission and possibly by carriers. Whilst his experiments were inconclusive he found in one case that burrows remained infective for at least six months. Plague was not persistent in a burrow for even one month in the absence of fleas. With fleas present infection persisted for two to three months and doubtfully up to four months. Fleas are capable of surviving for those same periods and remain infective.

Pirie found that vaccine washed off agar and heat-killed did not confer a high degree of immunity in gerbils. This vaccine was not of any use in treatment. Sensitized vaccines were not of much value in treatment and prophylaxis of plague in the gerbil.

Anti-plague serum was highly satisfactory in the treatment of guinea-pigs if given early and in large doses. In the gerbil serum prolonged life considerably but no ' cures ' were affected. Serum was less effective than

vaccine as a prophylactic in guinea-pigs and gerbils. True vaccination with live avirulent *P. pestis* give a higher degree of immunity in gerbils than killed vaccines.

Pirie further showed that there were virtually no morphological or cultural differences between South African and other strains of *P. pestis*. He laid stress on the pleomosphism of the organism and the occurrence of atypical forms even in the human body.

Apart from a few strains from a certain locality which ferment glycerine, South African strains are uniform in their fermentation reactions. Otten's test for distinguishing between *P. pestis* and *P. pseudotuberculosis* did not give clear-cut results but were in general agreement.

The differential medium of Unashe and Vielazon has a definite sphere of usefulness for rapid indentification of *P. pestis* cultures and the checking of the purity of stock strains. Agglutination tests showed the great variation in the agglutinability of different strains of *P. pestis*, but did not suggest any grouping within the species. Agglutinin absorption tests could not be carried out owing to failure to obtain agglutinating sera of high enough titre.

Pirie recorded the finding of plague bacilli in two rodents with no visible macroscopic or microscopic signs of plague. This suggested a carrier condition amongst these rodents.

Ingram 1927 surveyed the ectoparasites found in association with rodents and small carnivora that were suspected of being implicated in the spread of plague. Adult fleas survived for 27 days in glass tubes ; this period was prolonged to 60 days if they were placed in an old gerbil nest. Four species of wild rodent fleas were capable of sucking human blood and one species of the house rat can act in a similar capacity. He found a seasonal variation in the prevalence of two species of fleas commonly found on the veld rodents in the Orange Free State if not throughout the Union. He also showed that atmospheric conditions in the burrows of wild rodents differed considerably from those obtaining on the surface during the same season of the year.

In 1929 Pirie drew attention to the dissociation of *P. pestis* and the importance of selecting smooth colonies for the preparation of vaccine and serum.

In the same year Pirie experimented with Bacteriophage in the prophylaxis and treatment of plague. He found it inferior to vaccine but stated that partial success warranted further trials. His work was inconclusive as the result of his phage losing its virulence.

In 1935 Pirie and Grasset developed a concentrated antiplague serum according to the method of Brunner-Pinckus, and found that the concentrated product was four times more effective than the unconcentrated serum.

In 1938 Pirie and Grasset showed that live avirulent organisms gave rise to better protection as vaccine and produced better serum. Serum from avirulent bacteria and concentrated by the one process method was adopted as standard by the S. African Institute for Medical Research.

Following up the work on live avirulent vaccines and serum produced therefrom, Grasset in 1941 did a comparative test on various strains of avirulent bacilli from Java, Madagascar and elsewhere and concluded that

the Tjiwidej (rough) strain from Java, the ' 2 ' Haffkine P. 1904, K 120 (Rowland) strains were best for vaccines and that sera from T.W.R.+E.V. 76 had the same properties.

In 1942 the avirulent vaccine was used in the field and the small number of doses used suggested some protective properties superior to that of the killed vaccine previously used.

Murray and Davis in 1946 report on the susceptibility of various rodents to more accurately determined doses of an avirulent strain of *P. pestis* according to the method of Sokhey. The high susceptibility of *Mastomys coucha* to plague and its usefulness as a laboratory animal is shown.

Projected Work

According to an arrangement between the S.A.I.M.R. and the Government Health Department, a Plague Research Laboratory is in the process of being established under the direction of Mr E. Davis, Government Ecologist. The pathologist, apart from doing routine plague work, will carry out and assist in the carrying out of research work on problems of plague in South Africa.

The peculiar distribution of endemic plague areas and the sporadic outbreaks are unrelated to the distribution of the reservoir hosts, but there seems to be some relationship between the species of flea and the distribution of plague. It is proposed to investigate this problem in a series of flea transmission experiments.

An attempt will be made to elucidate the nature of the resistance of *Desmodillus auricularis*, the Namaqua gerbil to plague.

The ' carrier ' condition and ' latent ' plague in rodents is to be investigated both in the field and in the laboratory. Attempts to be made to induce a carrier condition.

Vaccines and sera will be tested and experiments conducted for their improvement. It is aimed to produce highly antigenic avirulent strains.

An avirulent live vaccine showing good antigenic properties against rodents may not do so against man. Tests utilizing poliomyelitis discard monkeys will be done.

The therapeutic action of antibiotics on plague, e.g. streptomycin will be tried.

An answer will be sought to the question : can *P. pestis* be made avirulent by continuous rodent-flea-rodent passage.

Phage-typing of *P. pestis* will be attempted.

Attempts will be made to improve the keeping qualities of vaccines, e.g. by drying in the frozen state.

Survival and multiplication of *P. pestis* in various species of fleas will be studied.

Possible causes of the flaring up of infection and of explosive outbreaks in the veld will be studied.

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9. RESEARCH ON ANAEROBES IN SOUTH AFRICA

The outbreak of the second World War forced South Africa to devote attention to the anaerobes, particularly to those causing gas-gangrene, because of the difficulty, and sometimes the impossibility, of obtaining supplies of antitoxin from overseas countries. Dr J. H. Mason was appointed to the staff of the S.A. Institute for Medical Research for the purpose of preparing gas-gangrene antitoxin.

Much research has been, and is being, carried out on the production of toxin, formol-toxoid and antitoxin of the tetanus bacillus. The experience of Glenny of the Wellcome Laboratories was to a large extent followed with gratifying results. For example, it was confirmed that to obtain high-titre antitoxin, horses must be rested for some months (after having received their primary stimuli) before an intensive course of immunization is carried out. Further, the stimulating effect of potash-alum on immunity production was fully confirmed. The work of overseas investigators on the titration of tetanus toxins by the flocculation reaction has been confirmed and, as in their work, two zones of flocculation have been encountered. Recently Dr Mason received a strain of *Clostridium tetani* from Dr Mueller of the Harvard Medical School ; preliminary investigation indicated that this strain, growing in a medium consisting of peptic digest of pig stomach and an infusion of ox heart, produces high-value toxin.

Mason's work on the gas-gangrene anaerobes may be briefly summarized.

Cl. speticum good toxin is produced in peptone infusion (horse flesh) broth containing 0·5 per cent glucose and 5·0 per cent serum-albumin (horse), using selected strains and an incubation period (37° C.) of twenty hours. The toxin is best titrated by the L+ method, using the intravenous route of injection in mice. A flocculation reaction can be obtained with most toxins, particularly when an enzyme-purified antitoxin is used, but usually the floccules appear slowly, the reaction is not sharp, and two zones are common. The L+ value is a fairly accurate guide to the antigenic value of a toxin as judged by the response of horses undergoing hyperimmuniza-

tion. Potash-alum added to toxin (0·5 per cent final concentration) greatly increased its antigenic value.

Cl. oedematiens sugar-free (Bact. coli fermented) peptone infusion (horse flesh) broth plus 5 per cent serum-albumin, inoculated with a selected strain and incubated for three days at 37° C. produces a highly antigenic toxin capable (particularly when alum is added to it) of stimulating horses to produce antitoxin of between 1,500 and 2,500 units per c.cm.

The addition of albumin (salted out with ammonium sulphate) to the broth has given brews of toxin five to ten times more potent (from an antitoxin-binding standpoint) than those obtained without it. The addition of whole serum or of globulin to broth will also give better toxins but these do not result in better antitoxin production probably because globulin, known to be more antigenic *per se* than albumin, is to some extent despeciated during the growth of the microbe and competes with the toxin as an antigen when injected into horses.

Oedematiens toxin flocculates with antitoxin and the remarks noted under *Cl. septicum* flocculation apply equally here.

Cl. Welchi (*perfrigens*) by far the greatest amount of research has been devoted to the toxin and antitoxin of this anaerobe. There are several reasons for this, the chief being the difficulty of obtaining potent toxin and consequently the difficulty of producing high-value antitoxin.

Strains and medium many strains have been investigated and Mason has found, in common with other workers, the strain 'S107' is an excellent toxin producer. Of the numerous media tried, meat particle broth (made from horse flesh and containing about half by volume of meat particles) is the most satisfactory for routine purposes. Without meat particles, very little alpha toxin is produced in any medium.

Concentration of toxin—Welch toxin may be concentrated and, to some extent, purified by standard methods such as ammonium sulphate, alcohol, and acetic acid precipitation. Such concentrated toxins are not better antigens, in so far as horse hyperimmunization is concerned, than the original toxin. Non-specific material, irritating when injected subcutaneously, and possibly antigenic in nature, is also concentrated and probably competes with the toxin as an antigen.

Mason has shown that welch toxin-antitoxin floccules may be dissolved in weak alkali (N/20 NaOH) ; most of the antitoxin is destroyed but about 50 per ent of specific antigen, mainly toxoid, is recovered. For horse immunization such dissolved floccules are not fully satisfactory, because despeciated antitoxin is present, and this can act as a competing antigen. Much of the despeciated antibody may be removed as a coagulum if *toxoid*-antitoxin floccules dissolved in weak alkali (and the pH, after an hour's interval, adjusted to 7) are boiled.

Such a recovered toxoid, relatively but not absolutely free from horse serum protein, is an excellent antigen for hyperimmunization of horses and, Lf for Lf, is much superior, in guinea-pigs, to the original parent toxoid.

Thermostability of Welch toxin—Mason has confirmed the observation that welch toxin is not totally destroyed when autoclaved. This has an important bearing on antitoxin production in a large serum institute. Here, in the section of the S.A. Institute for Medical Research dealing with the

gas-gangrene anaerobes, glassware is indiscriminately used for cultures or toxins of *Cl. welchii*, *Cl. septicum*, and *Cl. oedematiens* with, of course, a sterilization (autoclave) between each manipulation. In spite of this adequate sterilization, the serum from every septicum and every oedematiens horse contains welch antitoxin (3 to 35 units per c.cm.)

Welch antitoxin in the serum of normal animals. The sera of horses, cattle, sheep, rabbits, guinea-pigs and wild animals (different buck, wildebeets, wart-hog and zebra) have been examined. The most interesting observations have been the high values in zebra ($\frac{1}{2}$ to 1 unit per c.cm.) and in old milk cows ($\frac{1}{2}$ to $2\frac{1}{2}$ units per c.cm.).

We appreciate that if South Africa is to keep abreast with the work of overseas investigators, collaboration with the chemist and physicist is essential. For example, it is obvious that the interesting problem of the separation of welch toxin from the denatured globulin of dissolved toxin-antitoxin floccules is work for an experienced physical chemist. Other interesting problems abound in the anaerobic field, among them being flocculation of septicum, oedematiens, and tetanus toxins.

Summary

Up to the beginning of the second World War, little specialized work on anaerobes had been carried out in South Africa by medical bacteriologists. During the war period, gas-gangrene antitoxin was produced in the Union and this, of necessity, led to research on the causative microbes and their toxins and antitoxins. Among other things, methods of production, of concentration, and of titration of toxins were investigated.

10. TYPHUS FEVERS

In Southern Africa three forms of typhus fever are known to occur, namely epidemic louse-borne typhus, murine flea-borne typhus and tick-bite fever, the local variety of tick typhus. That tick-bite fever was a rickettsial disease transmitted by ticks was proved by Pijper and his co-workers. Pijper was also the first to demonstrate the occurrence of murine typhus in South Africa. This he did when he isolated a strain from rats caught in the Potchefstroom district and showed that it was similar in its characteristics to a strain isolated from patients suffering from typhus fever in Pretoria.

A systematic investigation of the typhus fevers occurring in South Africa was begun by Dr J. H. S. Gear at the South African Institute for Medical Research in 1935. The object was to determine their distribution, their possible reservoir hosts, and their vectors, and to study their clinical manifestations, to study the characteristics of the strains in laboratory animals, to study their relationship of the South African forms to similar diseases occurring elsewhere, and to work out diagnostic laboratory tests of differential value and to evolve a protective vaccine. Brief accounts of these investigations which are still being continued are given hereunder.

Tick-Bite Fever

It has been shown that tick-bite fever, or closely similar diseases, occur all over Southern Africa where ticks are prevalent. All the common species

of ixodid ticks have proved capable of transmitting the infection, including the common South African dog tick *Haemaphysalis leachi*. It was further shown that the infection is hereditarily transmitted through the egg from one generation to the next. This hereditary transmission can proceed indefinitely. All stages of the tick, the larva, nymph and adult were capable of transmitting the infection to experimental animals (Gear and De Meillon, 1939).

In searching for possible reservoir hosts, many species of rodents caught wild were examined ; in no case was a strain of tick-bite fever isolated from them. However, it has been shown that the striped mouse and the common South African gerbils are susceptible to the disease (Gear and Davis, 1942).

The transmission of the disease by contamination of the conjunctiva with material from infected ticks was shown to occur. That tick-bite fever in middle-aged and elderly people is often a serious disease with dangerous complications, the commonest of which is femoral thrombosis and that it is occasionally fatal also emerged from this study (Gear, 1929).

It was shown that the rickettsiae causing tick-bite fever grow prolifically in egg cultures, especially in the yolk sac membrane. Vaccines prepared from these cultures were shown to be effective in protecting experimental animals against tick-bite fever (Gear, 1940) (Bevan, 1943).

Later it was found that protective vaccines against tick-bite fever could also be prepared from suspensions rich in rickettsiae obtained from gerbils.

Murine Typhus

In the course of this study it has been shown that murine typhus is widespread amongst the urban rat population in Southern Africa (Gear, De Meillon and Davis, 1944) (Harington, 1945). Human cases are also regularly notified, especially in Natal and the Cape Province.

It was shown that fleas (*Xenopsylla cheopis*) removed from wild rats were capable of transmitting the infection to experimental animals under laboratory conditions (Gear and De Meillon, 1939).

It is possible to prepare vaccines from egg cultures and gerbil cultures of the causative rickettsiae, which confer a high degree of immunity on experimental animals (Gear and Davis, 1942 and Gear, Harris and Saner, 1942).

Epidemic Louse-borne Typhus

Epidemic louse-borne typhus is prevalent in South Africa, occurring especially in the Transkei, the Eastern Cape Province, the Orange Free State and the Eastern Transvaal.

A field study showed that the habits of the South African natives, many of them intrinsically very praiseworthy, were largely to blame for the prevalence and spread of this disease. It was proved that both varieties of the human louse *Pediculus humanus corporis* and *Pediculus humanus capitis* were capable of harbouring the infection (Gear, De Meillon and Davis, 1944).

It was found that in addition to being susceptible to murine typhus, the common South African gerbils (*Genus tatera*) were almost equally susceptible

to epidemic louse-borne typhus. Prolific growths of rickettsiae took place in the peritoneum, especially if the resistance of the gerbils had been lowered previously by exposure to X-rays (Gear and Davis, 1942). Later it was shown that by the use of these animals a prophylactic vaccine could be prepared. This vaccine conferred a high degree of immunity of experimental animals (Gear, Harris and Saner, 1942). This vaccine was produced on a large scale to immunize the African natives in the Transkei. An alum-precipitated vaccine for one shot immunization was also prepared for this purpose from suspensions of rickettsiae obtained from gerbils (Osburn, 1944).

In addition, the egg culture method of Cox was used at the Typhus Vaccine Laboratory of the S.A. Institute for Medical Research to prepare several million doses of vaccine for use in South Africa, North Africa and Europe. The rickettsial content concentration was found to be of great importance in determining the effectiveness of the vaccine (Bevan, 1943). The yield of rickettsiae from the egg was greatly increased by refinements of the technique and so it was possible to prepare vaccines with a high rickettsial content (Berkowitz, 1946). Ducks' eggs were found to be suitable for the preparation of epidemic typhus vaccine (Berkowitz, 1944).

The rickettsial complement fixation test was found to be of value in the diagnosis of typhus fever and especially in differentiating between the three forms of typhus occurring in South Africa (Wolstenholme and Gear, 1945).

Dr Gear is at present engaged on a study of the relationship between South African strains of typhus and those occurring elsewhere. Future work at the S.A. Institute for Medical Research will be continued along these lines of investigation. Attention will be devoted to testing various substances for the treatment of typhus fever and to improving the quality of the rickettsial vaccines. One practical aim of the investigators will be to determine the best means for the eradication of typhus fever from South Africa.

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11. VIRUS DISEASES

The virus diseases receiving special attention at the South African Institute for Medical Research are yellow fever, poliomyelitis and influenza.

Yellow Fever

With the assistance of the Rockefeller Foundation, the Union Health Department established a Yellow Fever Laboratory at the Rietfontein Branch of the South African Institute for Medical Research. The primary purpose of this laboratory is to prepare yellow fever vaccine to provide for the needs of the African territories. This laboratory has produced yellow fever vaccine since the beginning of 1945 and has been responsible for the supply of yellow fever vaccine in Africa since the beginning of 1946.

A modified yellow fever protection test, using D17 strain of virus, has been used by Dr J. H. S. Gear to carry out a preliminary immunity survey in the Union of South Africa and in the neighbouring territories. This has revealed that a certain percentage of bloods from Northern Bechuanaland gave positive protection tests. This finding has since been confirmed by a larger series of tests carried out by Dr Smitburn of the Yellow Fever Research Institute at Entebbe, Uganda.

Because of this finding, Dr B. De Meillon, entomologist of the South African Institute for Medical Research, is at present conducting a mosquito survey in the area. Bloods from possible reservoir hosts of infection from monkeys and bush-babies are also being collected and tested.

Future investigations will depend to some extent on the findings of the present work. The exact southern limit of the endemic yellow fever area will be determined as soon as possible. Once it has been determined it will require constant checking to note any change, particularly any southward extension.

Poliomyelitis

The serious outbreak of poliomyelitis in South Africa in 1944–1945 decided the Institute to begin again investigations into this crippling disease. These investigations have in the first instance been directed to determining the distribution of the virus of poliomyelitis in an affected community, and then to determining the methods by which the virus spreads. It has been shown that the common South African vervet monkey *Cercopithecus aethiops pygerythrus* is susceptible to the disease and, therefore, is a suitable animal for the investigation of poliomyelitis. As large numbers of these animals are readily available, an opportunity offers of a detailed investigation of the disease as it occurs in South Africa.

In the investigations carried out so far it has been demonstrated that in a small children's home in which a case of poliomyelitis occurred, the virus was excreted in the faeces of two of seven contacts. In one of these contacts the virus was again detected after one month, but not after two months (Gear, Yeo and Mundel, 1945).

Later, an outbreak in one of the suburbs of Johannesburg was studied. Of fourteen contacts of a known carrier of the virus, who subsequently developed paralysis, information was available about ten. Of these ten, two developed paralytic poliomyelitis, one developed a non-paralytic attack and seven remained in good health. The faeces of the case developing a non-paralytic attack and of the seven healthy contacts were tested for the presence of the virus. The virus of poliomyelitis was detected in the faeces of five of these eight individuals. From this investigation it was concluded that direct contact with a carrier of the virus was an important method of spreading poliomyelitis (Gear and Mundel, 1946).

The virus of poliomyelitis has been detected in the sewage in one of the sewage purification plants in Johannesburg. The settled sewage gave a positive test when tested in monkeys, but the effluent from the humus tanks after sand filtration gave a negative result. It appeared that the virus did not survive the process of sewage purification (Gear, Mundel and Wilson, 1946). In a later test, however, the virus was detected in the humus tank effluent as well as in the settled sewage. The irrigation of vegetable gardens by the effluent from sewage works is, therefore, considered to be a potential danger of infection.

These investigations will be continued.

Influenza

The large-scale production of anti-influenza vaccine was begun at the South African Institute for Medical Research in 1945. Investigations have so far been restricted to evolving the best methods for producing this vaccine.

The investigation of influenza, however, will be undertaken as opportunity occurs, especially when outbreaks occur amongst the mine native labourers. These communities of workers are relatively closed and are suitable for controlled large-scale experiments into the efficacy of the vaccine.

12. DIPHTHERIA

Racial Immunity : South Africa presents a favourable site for investigations into racial factors in relation to immunity. Germans in East Africa, and Belgian and French investigators in Central and West Africa made some observations on this problem many years ago. Turbott in New Zealand utilized the mixed populations of Maori and European stock for a similar purpose. He came to the conclusion that the degree of herd-immunity to diphtheria was directly related to the proportion of Maori blood in a given group. His valuable contribution to our knowledge of this subject does not appear to have been followed up though it was published in 1930.

Since that date Grasset, Higgins and others have shown the lower incidence of diphtheria in the South African Bantu. Dr J. F. Murray of the South African Institute for Medical Research has confirmed Grasset's findings and also the high incidence of Schick negatives in Bantu children as compared with European children of similar age groups. Murray surveyed the incidence of virulent and avirulent *C. diphtheriae* in large groups of urban and rural Bantu and showed that though virulent *C. diphtheriae* are equally common in rural and urban areas, clinical diphtheria is more common amongst the urban Bantu. The cause of this difference remains to be investigated.

Turbott's work should be repeated in our European, Bantu and Coloured populations and, if confirmed, the nature of the factor or factors leading to greater possible inherent and possibly acquired immunity to diphtheria in the African races should be worked out. There is some reason to believe that the Bantu in South Africa respond more rapidly to antigenic stimulus in diphtheria than do Europeans but this requires more detailed investigation. If confirmed the causes for the rapid response must be worked out whether environmental (as Grasset postulated), or genetic (as Turbott suggested), or a combination of both (as Murray thought).

Preliminary work in relation to Scarlet Fever and the Streptococcus haemolyticus in the Bantu suggests that a similar state of affairs exists there also. If so, closer investigation might reveal useful facts concerning immunity in general.

Incidence of gravis strains : Over a period of years the strains of *C. diphtheriae* occurring in Johannesburg have been classified into *gravis*, *mitis* and *intermediate* types. During that period diphtheria has been clinically mild and has shown a high proportion of *mitis* and *atypical* strains. South Africa, especially in view of frequent troop movements in recent years, might at any time show an increase of *gravis* strains. There might then follow a serious type of clinical diphtheria with a high proportion of *gravis* strains, an association which has frequently been observed elsewhere. By continued observation and correlation of clinical and laboratory findings in an area where *gravis* strains are, at present, of little importance something might be learned of the factors inducing the change.

13. BILHARZIASIS

Except for some work on clinical and therapeutic aspects little research has been done on this disease in South Africa. Dr A. Porter, sometime

parasitologist to the South African Institute for Medical Research, Dr J. G. Becker, at present on the staff of the S.A.I.M.R. and Dr Cawston of Durban have contributed valuable evidence on the vectors of bilharzia in South Africa. The fullest work is that of Dr A. Porter, who in 1938 published a large monograph entitled ' The larvae Trematoda found in certain South African Mollusca, with special reference to Schistosomiasis,' *Publ. S. Afr. Inst. med. Res.*, **8**, 1-492. (Copies of Dr Porter's monograph are available to delegates.) Dr Porter gave maps of the distribution of snails and human cases as well as much information on life cycles, etc. Since the departure of Dr Porter the S.A.I.M.R. and the Union have been without a research parasitologist.

In spite of the work that has already been done the position with regard to our vectors, of both urinary and intestinal bilharzia (their identity, bionomics, distribution, spread and control), is by no means clear. What is more important is that virtually no work is being carried out anywhere in the Union on these questions. *Limnaea natalensis*, for example, is generally accepted to be a vector of urinary bilharzia ; yet all recent attempts by Dr De Meillon of the S.A.I.M.R. and Dr Monnig of the Onderstepoort Veterinary Laboratories have failed. The question of whether *L. natalensis* is a vector or not is an important one since it is very widely distributed.

Dr Porter pointed out in his monograph that the distribution of the snail vector is much wider than that of the disease. This is clearly a very important matter since it means that steps could be taken to prevent the spread of bilharzia to uninfected areas.

There is no doubt that bilharziasis is a serious disease in many parts of South Africa and that infection is spreading. Research on all aspects is urgently required.

14. MEDICAL ENTOMOLOGY

The Union of South Africa is served by only one medical entomologist, Dr B. De Meillon, employed by the South African Institute for Medical Research. The first appointment was made in 1924 when Dr A. Ingram, who had retired from the West African Medical Service, joined the staff of the Institute. In 1926 Dr B. De Meillon was appointed as assistant to Dr Ingram, and later took charge of the department when the latter retired.

Before 1924 medical entomology in South Africa was bound up with veterinary and agricultural entomology, consisting largely of sporadic collecting of blood-sucking insects which were mostly sent overseas for identification. Among those early workers mention must be made of Hill and Haydon, who in 1905 showed that *Anophiles gamliae* was a vector of malaria in Natal and later (1907) published an account of the early stages of Natal anophelines. At Onderstepoort Bedford did much towards increasing our knowledge of the South African fauna and in 1928 published a work on South African mosquitos.

When Dr Ingram came to South Africa in 1924 he found that the insect fauna was so little known that he decided to concentrate in the first place on the very important matter of making collections and having them named and where possible naming them himself. This work has been continued by Dr De Meillon and will have to continue for some time to

come. The result of this policy has been that the S.A. Institute for Medica Research now houses representative collections of *Culicidae, Simuliidae, Ceratopogonidae* and *Siphonaptera.* The Entomology Department of the Institute is now in a position to name any Ethiopian species belonging to those families. Use is made of this facility by authorities in other parts of Africa and several entomologists have come to Johannesburg to study the collections at the Institute.

At the same time that our fauna was being investigated from a systematic point of view work on bionomics was also carried out. For this purpose the S.A. Institute opened and maintained a Malaria Research Station, first at Tzaneen in the Northern Transvaal (1931–1934) and later at Eshowe, Zululand (1934–1938).

Dr De Meillon has on several occasions accepted invitations to other territories to advise on matters connected with medical entomology. These territories include Portuguese East Africa, N. Rhodesia, Swaziland, Bechuanaland.

Malaria

Systematic work at Johannesburg has made it possible to recognize all our known anophelines in adult and larval stages. This knowledge is used very extensively in a practical manner by the Union Health Department and other authorities concerned with the control of malaria. Dr De Meillon recently completed a review of the Anophelini of the whole Ethiopian region. This work is to appear in America.

Work on the bionomics of our vectors formed an important item during Dr De Meillon's residence at the field stations at Tzaneen and Eshowe. Contributions he made in this direction included (i) a study of breeding places of vectors and other species ; (ii) the identification of South African vectors of malaria ; (iii) a study of the meteorological factors influencing the distribution of vectors and a forecast of the territory in which they are likely to be found or which one of them, namely *A. gambiae*, is likely to invade ; (iv) a detailed study of *A. funestus* and *A. gambiae* and their relation to malaria which resulted in an explanation of the epidemiology of malaria in the Union ; (v) a study of the behaviour of vectors in African huts ; this assisted in the development of anti-adult spraying as a measure for the control of malaria. This valuable measure is now employed in many parts of the world. (*Trans. R. Soc. trop. med. and Hyg.*, 1944, **38**, (3) p. 189.)

Typhus

Dr De Meillon's studies in typhus (conducted in collaboration with Dr J. H. S. Gear) have been mainly concerned with the identification of the vectors of the disease. Some of the more important results obtained were : (i) successful transmission of tick-bite fever by the bite of the dog tick *Haemaphysalis leachi* ; (ii) hereditary transmission of *Rickettsiae* of thick fever through several generations of ticks without the intervention of a human host,—these findings have contributed in no small measure to the clearing up of the epidemiology of urban tick-bite fever ; (iii) successful transmission of murine typhus by the bite of the rat flea, *Xenopsylla cheopis* ; (iv) demonstration that Transkeian typhus is mainly louse-borne, both the head and the body louse being capable of transmitting the disease.

Reference must also be made to the important contributions by Pyper and Dan (*Lbl. Bakt.*, 1934, 133, F) who showed that the ticks *Amblyomma hebraeum*, *Rhipicephalus appendiculatus* and *Boophilus decolorabus* could harbour the virus of tick-bite fever. In addition, Alexander and Mason (*Acta Conventris tertii de Tropicis Morbis*, p. 526, 1938) isolated a strain of tick-bite fever by allowing the tick *Hyalomma aegyptium* var. *impressum*, which had been taken on a wild hare, to feed on guinea pigs.

Plague

Apart from some early work by Dr Ingram on the transmission of plague by some fleas of wild rodents entomological work on plague has largely been concerned with a flea survey of the whole Union. The technique of the survey was worked out by Dr De Meillon in collaboration with Mr D. H. S. Davis, ecologist to the Union Health Department. Mr Davis' field staff is largely responsible for the collecting of fleas and their hosts. The flea hosts are identified either by Mr Davis or by Captain Shortridge of the Kaffrarian Museum, and the fleas by Dr De Meillon who is also responsible for keeping all the records and collections. The survey has covered virtually the whole of the Union and there can be few South African insects which are now so well known as the fleas.

Among other things the flea survey has shown that there is good reason for believing that sylvatic plague is absent from those parts of the Union where *Xenopsylla eridos* and *X. piriei* do not occur.

Outside the South African Institute for Medical Research the only work on the entomology of plague is being done by Mr Davis, who has collected considerable data on host preferences and certain aspects of flea ecology. Mr Davis works in close collaboration with the Institute.

Yellow Fever

The need for investigations into the entomology of yellow fever has often been stressed but so far very little has been done. Apart from some collecting by early veterinary entomologists the only systematic surveys have been made by Dr De Meillon. These surveys have largely been confined to the malarious areas of the Union. We have very little knowledge of the distribution of the possible vectors of yellow fever in the rest of the Union, such as S. Natal, Orange Free State, Cape Province, South West Africa.

Recent work has shown that yellow fever exists on the borders of the Union. More important still is the fact that it is from these infected areas that much of the labour for the gold mines of the Transvaal is recruited.

Relapsing Fever

Although the vector *O. monbata* has been known to occur in South Africa for a long time and relapsing fever since 1912 (Ross. 1912. *Trans. med. J.*, F. 125) it is only recently that the importance and wide distribution of the tick and the disease has been realized. Bedford of Onderstepoort gave the distribution of the tick as known until 1936 ; since that date Dr D. Ordman of the S.A.I.M.R. has added considerably to our knowledge.

Apart from the diseases and their vectors mentioned above work on household insect pests, their bionomics and control is largely in the hands

of the Division of Entomology of the Union Agriculture Department. Numerous pamphlets on this subject have been issued and one book published (Brain, C.K. 1929. *Insect Pests and their Control in South Africa*, Nasionale Pers Beperk, Cape Town).

Work on other insects of importance mainly to veterinary science, such as tsetse flies and ticks is largely carried out at Onderstepoort by the Division of Veterinary Science of the Union Agricultural Department.

Insect Physiology

Dr De Meillon has carried out a series of investigations on insect physiology in collaboration with Dr L. Golberg (also of the S.A.I.M.R.). Much progress has been made in a study of the nutritional requirements of the larva of the yellow fever mosquito (*Aedes aegypti*) ; so far three papers have been published. This work is still in progress as are studies on the physiology of the bed bug.

Comment

As the major human diseases indigenous in and threatening the Union are insect born, it is essential that more medical entomologists with trained assistance must be appointed if we are to deal adequately with these problems.

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15. MEDICAL ECOLOGY

A recommendation contained in the Annual Report of the Department of Public Health, 1936, led to the appointment in 1938 of an animal ecologist (Mr D. H. S. Davis) to collate existing data on the field aspects of sylvatic plague in South Africa and to carry out field research into outstanding problems. The programme of research drawn up depended for its successful prosecution upon close collaboration with the South African Institute for Medical Research in entomological and bacteriological studies. Up to the outbreak of war intensive studies were carried out in an endemic plague area in the northern Orange Free State and the foundation was laid for a broad attack on the field problems. Increases in staff and laboratory facilities were ruled out by the outbreak of war and Mr Davis gave more and more of his time to the practical aspects of anti-plague work.

In co-operation with members of the staff of the South African Institute for Medical Research, a certain amount of basic investigation was done. The survey of the rodent fleas of the Union was carried on on a reduced scale and experimental work was done on the use of wild rodents adapted to the laboratory as experimental animals for plague, typhus and tuberculosis investigations.

The field work on the population dynamics of gerbil (*Tatera*), the primary reservoir of sulvatic plague, had advanced far enough to be of practical value in the production of anti-typhus vaccine.

When it was discovered that gerbils could be used for this purpose, the technique of live-trapping, developed to study movements of individual gerbils in a colony, was employed to provide the typhus laboratory of the South African Institute for Medical Research with about 5000 gerbils a month.

The value of linking field and laboratory investigations in technological and basic research was clearly demonstrated. These early endeavours have found practical expression in the founding of a Plague Research Laboratory jointly by the Union Health Department and the South African Institute for Medical Research. The Health Department will contribute the field facilities and the laboratory building while the Institute provides the laboratory facilities. The Health Department has agreed to provide the ecologist with an assistant ecologist, a laboratory technician (zoology), two field inspectors and the part-time services of an epidemiologist and an entomologist. The Institute has agreed to provide a pathologist and two laboratory technicians (pathology and entomology).

When fully staffed it is proposed to continue plague investigations on the lines developed by the ecologist and gradually to expand the sphere of activities to include other animal reservoir diseases such as murine typhus and yellow fever, which depend for their comprehensive study on the application of ecological methods.

In this way it is hoped that the present Plague Research Laboratory will

eventually develop into a Laboratory of Medical Ecology designed to conduct comprehensive investigations into animal reservoir diseases, in Southern Africa.

Plague Investigations. 1938–1945

Gerbil Ecology

Bionomics

Gerbils of the genus *Tatera* form the primary reservoir of plague in Southern Africa. *Tatera* brantsi is the commonest species of the hyper-endemic areas of the highveld of the northern Orange Free State and southern Transvaal, and was singled out for intensive investigation. During the year 1938–1939 its basic ecology was studied in the northern Orange Free State. Investigations were made of its distribution and colony strength, its feeding and burrowing habits, its reproductive behaviour, the relative abundance and seasonal prevalence of fleas, and its interrelations with other wild rodents, and domestic rodents (Davis, D. H. S., 1939). These studies were made during an inter-epizootic period and plague was not isolated from the experimental area.

Epizootic cycle

In the course of these preliminary investigations a possible method of census emerged, based on the number of occupied burrows. In the following year (1940) when this field station had been given up, an opportunity of studying an epizootic presented itself in an area some fifty miles to the north. Gerbil colonies over an area of about 100 square miles were kept under observation for twelve months, during which time the population declined from an initial estimated strength of about two thousand to a few individuals. The course of the epizootic was followed by burrow census counts, standardized during the work, which gave an accurate picture of relative rates of decline of the population.

P. pestis was isolated as suitable material was found by inoculation in the field of organs from dead rodents and of emulsified fleas. Bone marrow proved to be a reliable source of *P. pestis* even in putrid carcases. Infected fleas were recovered from burrows before active signs of the epizootic could be detected and up to three months after a warren had been abandoned and unvisited by other rodents. There were some forty colonies in the area ranging from half a dozen to over fifty individuals at the start of the epizootic. Each colony, whatever its size, took three to four months to die out and there was no indication of wave infection from one to another. Even in large colonies, decline was uniform over the occupied area. The study emphasized the importance of the normal range of movement of gerbils within a warren and between one warren and another. The average distance apart of the colonies in this area was about two miles and the degree of interchange could only be studied by marking methods. The next field operation was therefore directed to developing a marking system which would enable the movements of individual gerbils to be followed with a view to applying the technique to studying the recrudescence and spread of enzootic plague.

Inter-warren movement

A colony, about 200 strong, was selected (1942) south of Johannesburg on the fringe of the northernmost extension of the enzootic plague area. The gerbils were marked by ear notching and toe clipping. In general, the main conclusions were as follows : Female gerbils have a strong affinity for the warren or group of warrens in which they had their first litter, whereas males circulate rather more and were less tied. Each night the majority of the gerbils came into ' relay ' contact through movement between adjoining warrens. No evidence was obtained to support the view that members of whole warrens moved en bloc from one warren to another, nor that individual gerbils indulged in regular ' visiting ' of a series of warrens. Young animals of both sexes sometimes moved widely after puberty to establish themselves in new places away from the home warren.

The rate of replacement of the colony, which remained more or less at the same population level, was high, and although no definite evidence of emigration was obtained it is believed that loss of individuals through accident or natural death rather than emigration accounted for those that disappeared. The mean length of life was little more than twelve months, although a few individuals reached a known age of eighteen months. This experimental colony was destroyed in August 1943, during routine anti-plague operations necessitated by recrudescence of plague in the old enzootic area.

Reproductive cycle

Crude data on the reproductivity of gerbils in the highveld (*T. brantsi*) and in the Western Cape (*T. afra*) have been collected and show that the annual breeding rhythm is bimodal, there being less breeding in mid-winter and mid-summer. A project for accurately determining the annual cycle of *T. brantsi* and *T. afra* is under way in collaboration with the Zoology Department, University of Cape Town. This investigation is linked up with laboratory experiments designed to discover the gerbil's requirements for breeding in the laboratory.

' *New Systematics* '

There are three well-defined species of *Tatera* in South Africa—*T. brantsi* (highveld and Kalahari), *T. afra* (Western Cape and Cape Coastal) and *T. lobengulae* (Transvaal bushveld and Kalahari). Numerous sub-species have been described. *T. brantsi* and *lobengulae* overlap, particularly in the Kalahari and provide a field for the study of the interrelations of closely allied species. Several thousand skulls have already been collected for craniological study in regard to age-determination, growth-rates and taxonomic differences.

Flea Survey

The National Flea Collection is housed in the Entomology Department of the S.A.I.M.R. where all identifications have been done. Since 1938 every flea collected has been retained in the collection as new species are continually cropping up differing in minor but distinct and, often in the past, unrecognized characters.

The rodent fleas are now fairly well known, although the plague-free

region of Natal has not yet been adequately surveyed. Comparison of the flea fauna on gerbils in plague-free and plague infected regions shows clearly that the presence of plague is closely bound up with the species of flea prevalent on gerbils.

Xenopsylla eridos and *X. piriei*, the gerbil fleas of the highveld and karroo respectively, are absent or only sparingly present outside the enzootic plague area. They are replaced by closely allied species on gerbils in the plague-free region. Although the common rat fleas of tropical and temporate countries (*X. cheopis*, *Nosopsyllus* fasciatus, *Leptopsylla segnis* etc.), are present in the towns, house rats and other domestic or semi-domestic rodents are parasitized almost exclusively by *X. brasiliensis*. *X. brasiliensis* is indigenous to Africa and has been carried to South America and India and probably re-introduced into South Africa, from time to time. Its natural habitat appears to be in the Kalahari sandveld and other parts of South Africa in which the rodent *Aethomys* occurs. It is rare on other wild rodents and is found on gerbils as a stray only from domestic rats.

The results of the flea survey indicate clearly the species which need laboratory investigation to determine their vector efficiency, a subject as yet untouched but of vital importance.

Adaptation of wild rodents to the Laboratory

Mastomys coucha (multimammate mouse)

One of the early aims was to adapt wild rodents to laboratory conditions. Mastomys was the first to be bred successfully and a stock has been maintained in captivity since 1939. It was soon proved to be highly suitable as a plague test animal. It was easily bred and uniformly susceptible to small doses of *P. pestis* and has been adopted as the standard test animal for routine and experimental work (Davis and Murray, MS. in prep.).

Mystromys albicaudatus (white tailed rat)

Mystromys, an ally of the hamster, also bred. It is uniformly susceptible to plague. It appears to have other possibilities ; some were inoculated with kala-azar at the Stack Laboratory, Khartoum, and showed a heavy but inapparent infection. The division of Veterinary Services, Onderstepoort, have shown that it is susceptible to heartwater (*Rickettsia ruminantium*), and is of particular value in that the organism gains in virulence in *Mystromys* whereas it loses virulence in ferrets, the only other small laboratory animal yet known to be susceptible.

Tatera spp. (gerbils)

Success has not yet attended the breeding of gerbils in captivity, but wild-caught specimens are easily procurable. Gerbils were used in the mass production of anti-typhus vaccine, following the discovery (Gear and Davis, 1942) that they were susceptible to the Rickettsiae of louse- flea- and tick-borne typhus in South Africa. They are susceptible to Well's acid-fast (vole) bacillus and to bovine tuberculosis, but so far have proved rather resistant to human tuberculosis (including SARANAC) (Murray, Grasset and Davis, in press). The gerbil has also been found to react very quickly to vitamin deficient diets and holds out promise of being a useful experimental animal in this direction.

Future Investigations

There are two major problems : (1) to account for the present distribution of plague, and (2) to determine the mechanism responsible for the persistence of infection from one epizootic to another. It is proposed to establish field stations at which long-term research into all phases of the epizootic cycle can be investigated by the methods of census, etc., which have been developed, and to co-ordinate field observations with laboratory studies.

Gerbil ecology. So far the different phases of the epizootic cycle in gerbils have been studied separately. It is proposed to study all aspects—reproduction, parasites, movements, numbers, etc.—in one area. In addition to this long-term programme, short-term investigations will be made to clear up certain points, especially in connexion with the flea survey.

Flea survey. A uniform system of mapping, using latitude-longitude co-ordinates and a specially printed map, has been adopted to facilitate the analysis of the many factors influencing flea distribution and abundance in Southern Africa. A monograph on the systematics and ecology of South African fleas is contemplated. When the plotting of existing data has been done and some of the more important gaps in our knowledge have been filled, it will be possible to start on compiling the monograph. The flea survey provides the basis for selecting ' key ' flea species for the preliminary work of examining the vector efficiency of fleas in plague and plague-free area.

Utilization of wild rodents in the laboratory. As opportunity permits other species of South African wild rodents will be adapted to laboratory conditions and tested for their suitability in the study of plague, typhus and other diseases as heretofore. As already mentioned a special attempt is being made to breed gerbils in the laboratory.

Other Animal Reservoir Diseases

YELLOW FEVER

With the Yellow Fever Research Institute, Entebbe, as focussing point, it is hoped that this laboratory will be able to further knowledge, particularly of monkey ecology, within and beyond the borders of the Union, and to contribute from this point of view to entomological and virus investigations which the S.A.I.M.R. and the Union Health Department are contemplating as their contribution towards a comprehensive survey of yellow fever in Southern Africa. The Union has been ' assigned ' the Limpopo as its first field of operations to determine whether the endemic yellow fever zone extends there or not.

TYPHUS

Murine typhus is widely distributed in South Africa and although it is not of very great epidemiological importance, there is adequate field material for much useful work on vectors, reservoirs and the relationship with louse and tick-borne typhus.

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16. HAEMATOLOGY

Though no complete survey has been carried out routine investigation of blood pictures from clinical cases in the Bantu suggests that the distribution of blood dyscrasias, with certain notable exceptions, broadly resembles that in Europeans.

Macrocytic anaemia. A noteworthy feature is the rarity of pernicious anaemia in the Bantu. To determine the cause of this would be a valuable investigation. Also, although many of the Bantu suffer from malnutrition, it has been noted that severe macrocytic anaemia such as that observed in India, Greece, and elsewhere is uncommon. Foy commonly found macrocytic anaemia of pregnancy in the natives of Portuguese East Africa and yet it was only with difficulty that we were to find two or three cases in the Bantu in Johannesburg over a period of several years. This anomalous finding requires investigation.

Blood dyscrasias due to drugs. Blood dyscrasias due to arsenicals are not infrequently encountered in the Bantu but cases of agranulocytosis and of haemolytic anaemia due to sulphonamides are seldom observed. Only an adequate survey will show whether this is really due to a low incidence or to some other cause. If the incidence is as low as it appears to be when compared with Europeans further investigation might yield useful results.

Onyalai. Onyalai in natives of South Africa is sufficiently common to make it a serious problem. There is suggestive evidence that some cases at least are due to the use of native medicines. But the exact causative factors in this important and frequently fatal disease require investigation by a team of workers including the haematologist, the pharmacologist, the clinician and perhaps the social worker.

Sickle Cell Anaemia. Several surveys have shown the sickling trait in less than 0·25 per cent of South African Bantu (Murray, Altmann). On the other hand English in Northern Rhodesia found the trait in ± 17 per cent of the native population but observed only one or two clinical cases. But on the East Coast of Africa, though the trait occurs in approximately the same proportion of the native population (± 20 per cent), frank sickle cell anaemia occurs in ± 5 per cent. This discrepancy between sickle cell incidence in the Bantu and the Negro populations of Africa warrants an investigation, not only along haematological lines, but also from the point of view of the anthropologist.

These few examples indicate something of the field of haematological research at hand in South Africa which is, as yet, almost untouched.

17. PERIPHERAL CIRCULATION

Professor R. H. Goetz has been interested in problems of the blood circulation for many years. He had evolved a quantitative (optical, plethysmographic) method for measuring peripheral blood flow. When, therefore, he was appointed in 1937 to a research scholarship at the University of Cape Town he immediately commenced on investigations into the nature of certain vascular disorders of the limbs, such as Raynaud's disease, thromboangiitis obliterans and arteriosclerosis. He continued to work mainly on vascular diseases and in 1945 was appointed to the specially created Research Associate Chair in the Department of Surgery.

At first his investigations were mainly concerned with the diagnosis and differential diagnosis of these conditions (1) * and special investigations into the rate and control of the peripheral blood flow had to be carried out to arrive at standards with which to compare the blood flow in the various pathological conditions (2). The investigations carried out in man were supplemented by animal experiments where surgical intervention could be undertaken to control experimental conditions (3, 4). It was only later that the question of therapy was investigated. By assessing the exact degree of organic occlusion and of arterial spasm in these cases, the method proved most valuable and made it possible to determine more correctly the indications for treatment in general and for sympathectomy in particular. This led to a special study of the sympathetic innervation of the extremities. Confirming the work of others, it was realized that conventional sympathectomy of the upper extremities did not yield satisfactory results and a new method of performing sympathetic denervation of the upper extremities was developed. It was pointed out in an article (5), together with Dr J. A. S. Marr, that the sympathetic innervation of the arm could be successfully interrupted by the removal of the second thoracic ganglion only, which operation constitutes a preganglionic ramisection, in contrast to the post-ganglionic ramisection resulting from removal of the stellate ganglion which is the older method. Two new approaches for the removal of the second thoracic ganglion were described, one by open thoracotomy, and one through the thoracoscope. In the article it was briefly indicated how both these approaches might be used for excision of other than the second thoracic ganglion as well as in the treatment of other than peripheral vascular disease.

Knowing that our plethysmographic method was capable of estimating the blood flow through the skin only, and that in many cases symptoms might arise from the muscular system alone, it became important to conduct special investigations into the blood flow through the muscles in general and of the blood flow through the muscles of patients suffering from intermittent claudication especially. The available methods being very crude, a special apparatus was evolved by which claudication could be exactly measured and a so-called claudication index obtained (6). The claudication index in the normal was determined and contrasted with the indices obtained in various vascular diseases. A special test was devised for studying the vascular reserve, by comparing the claudication indices before and after complete arterial occlusion. Furthermore, the method

* See Bibliography on page 517.

was used to follow up the effect of treatment. Both the plethysmographic measurement of the blood flow through the skin and the ergographic index of the blood supply to the muscles made it possible for Goetz to follow up the results of various types of treatment in his patients to a degree hitherto unknown.

Special studies were carried out on the effect of nicotine and smoking in peripheral vascular disease and it was pointed out (7) that there is no convincing evidence that smoking is one of, or the etiological factor, in thromboangiitis obliterans. However, it causes a marked diminution in the peripheral blood flow and therefore it must be regarded as an aggravating factor in a patient exhibiting vascular disease.

Diabetic gangrene was dealt with in a publication (8) stressing the necessity of assessing exactly the arterial background in these cases with particular reference to the collateral circulation. The treatment would depend greatly on whether one was dealing with a primary arterial occlusion or with gangrene due to infection. The high operative mortality in these cases following major amputations was stressed and newer surgical methods aiming at overcoming this calamity were given prominence.

While Goetz's earlier investigations dealt with peripheral vascular disease in a strict sense, he has in recent years widened their scope and he became interested in problems related to hypertension, the pathological physiology of the autonomic nervous system and lately also in congenital heart diseases as far as they are amenable to surgical treatment, as well as other problems related to the circulatory system.

Thus during the past two years he has devoted a considerable amount of time to the investigation of cases suffering from scleroderma and has demonstrated (9, 10) that this condition does not affect the skin only, but has to be regarded as a systematic disease. It was pointed out that actually the more serious pathology occurs in the viscers and that the term 'scleroderma' was entirely inadequate and should be replaced by one more appropriately expressing the systemic nature of the disease. The title 'Progressive Systemic Sclerosis' was suggested and a paper demonstrating the pathology in the various organs, notably the heart, intestine, kidney and the musculocutaneous apparatus, was published (10).

In a paper published in the *S. Afr. Medical Journal* (11) a classification of the peripheral vascular diseases was presented, the clinical and special examination of such cases discussed, and a new technique for arteriography described. The value of plethysmography, particularly in the diagnosis of the earliest lesions, when other methods do not yield abnormal values, was demonstrated. More proof to this effect was furnished in a recent paper in the *American Heart Journal* (12), in which the evaluation of the plethysmogram with particular reference to the collateral circulation was dealt with in extenso.

Two theses have been prepared in Professor Goetz's department, one by Dr J. du Toit, on the Blood Flow in Cases of Poliomyelitis (13), and the other by Dr E. Malherbe on the Open Ductus Arteriosus Botalli (14). The latter thesis was accepted by the Faculty with honours and constitutes a most comprehensive study of the clinical signs of, and the surgery on, cases of patent ductus arteriosus. During the course of these investigations a new test was evolved which may become of considerable importance in

the diagnosis of this condition when differentiating it from such cardiac disturbances as it may be confused with. A paper is under preparation.

Dr F. Ames has started research work on sympathetic vasodilator fibres in man. However, no finality has yet been reached and a considerable amount of work has still to be done.

Recognition of the work done in the department has come not only through the literature but in other ways as well. In 1944 Surgeon-Commander C. C. Ungley obtained leave from the Royal Naval Medical Corps to work in the department on problems of the sympathetic nervous system, and in March 1946, Dr H. J. Bluntschli, M.D. (Lausanne) started research work there ; he had been granted a scholarship for two years by the Swiss Foundation for Biological and Medical research to carry out research on peripheral vascular diseases, and to become acquainted with the methods used in our department.

The following publications have emanated from the department :

(1) 1940. Plethysmography of the skin in the investigation of peripheral vascular diseases. *Brit. J. Surg.*, **27**, 506.

(2) 1943. The rate and control of the blood flow through the skin of the upper extremities. *S. Afr. med. Sci.*, **8**, 65.

(3) 1939. The nervous control of the blood flow through the skin as studied by the effect of adrenaline. *Quart. J. Exper. Physiol.*, **29**, 239.

(4) 1939. The control of the blood flow through the intestine as studied by the effect of adrenaline. *Quart. J. Exper. Physiol.*, **29**, 231.

(5) 1944. The importance of the second thoracic ganglionf or the sympathetic supply of the upper extremities. *Clin. Proc.*, **3**, 102.

(6) 1942. Ergographic studies. *Amer. Heart J.*, **23**, 782.

(7) 1942. Smoking and thromboangiitis obliterans. *Clin. Proc.*, **1**, 190.

(8) 1942. Diabetic gangrene. *Clin. Proc.*, **1**, 103.

(9) 1942. Note on a case showing Raynaud's Phenomenon and additional manifestations. *Clin. Proc.*, **1**, 244.

(10) 1945. The pathology of progressive systemic sclerosis (generalized scleroderma). *Clin. Proc.*, **4**, 337.

(11) 1945. The classification and diagnosis of peripheral vascular diseases. *S. Afr. med. J.*, **19**, 91.

(12) 1946. The rate and control of the blood flow through the skin of the lower extremities. *Amer. Heart J.*, Feb.

(13) du Toit, J. The blood flow in cases of Poliomyelitis. *Thesis.*

(14) Malherbe, E. The surgery of the Patent Ductus Arteriosus and the problem of its post-natal closure. *Thesis.*

MALARIA IN THE AUSTRALIAN REGION

By Dr FRANK FENNER, M.B.E., Malariologist, L.H.Q., S.W.P.A., 1943–1945

INCIDENCE

IN the Australian region malaria occurs in a few areas of northern Australia, north of latitude 20° S. and throughout the islands of Melanesia, i.e. on the mainland of New Guinea and in its associated island groups, New Britain, New Ireland, the Solomon Islands and the New Hebrides. Malaria does not occur on the islands west of 170° East longitude (Fiji, New Caledonia, Samoa, etc.).

AUSTRALIA

The present distribution of malaria on the Australian mainland corresponds with that of *Anopheles punctulatus moluccensis*.

In Queensland malaria is almost completely confined to the area north of Innisfail. Generally it has shown a low and smouldering endemicity along both sides of Cape York Peninsula with more persistent centres at Cairns and Yarrabah (spleen rates in 1944, 5·1 per cent and 7·8 per cent respectively) in the east, and the Staaten river in the west. This low endemicity has flared into definite outbreaks at irregular intervals in scattered localities, when the disease has occasionally extended inland, especially in mining areas. Cairns has suffered several such outbreaks, the last being in 1942, when there were over 700 civilian and a few military cases of *vivax* malaria. Transmission occurred in April, May, June, at the end of the wet season.

Indigenous malaria south of Innisfail is everywhere a sporadic disease of rare occurrence, as it is also in New South Wales. In the presence of large numbers of gametocyte carriers, localized outbreaks of *vivax* malaria have occurred recently in isolated areas such as Sellheim and at Townsville.

The malarial history of Northern Territory has been one of usually localized outbreaks, associated with the development of endemic foci in the native population. These endemic foci now appear to exist in the lower reaches of all the main river systems, the Roper, the Alligators, the Daly, the Fitzmaurice and Victoria rivers. Outbreaks of malaria have occurred at various places but generally they do not extend above the upper reaches of the river systems. The last was in 1929–1934. Most of the outbreaks were *falciparum* malaria but all recent locally contracted cases have been *vivax* malaria. *Anopheles punctulatus moluccensis* is probably the principal vector.

MELANESIA

Malaria has always been the most important health problem of Melanesia. Among the native peoples it has limited population and thwarted develop-

ment. In recent military operations it has caused great sick wastage in Australian, American and Japanese military forces, with a high mortality rate when medical services were inadequate.

The anopheline vectors are *Anopheles punctulatus punctulatus* and *Anopheles punctulatus moluccensis*, and they cause hyperendemic malaria on the coastal lowlands of all the islands and along the great inland river systems of New Guinea. The highlands above 3,500 feet are non-malarious. Spleen rates amongst the native villages in the lowlands throughout the islands vary from 40 per cent to 100 per cent.

In most parts of Melanesia temperature and humidity are such that transmission occurs freely right through the year. In some exposed coastal villages the strong south-east trade winds cause a relative absence of mosquitoes during that season and in Port Moresby and Merauke there is very little transmission during the cool dry south-east season (June–October).

Blackwater fever has occurred amongst newcomers (Europeans, Malays, Japanese) in all parts of Melanesia. It was particularly common during the occupation of Tanah Merah in Dutch New Guinea and during the early mining rushes of Wan-Salamaua and Yodda goldfields.

ANOPHELINE VECTORS

The only important vectors are *Anopheles punctulatus punctulatus* and *Anopheles punctulatus moluccensis*. They breed in similar situations, especially in shallow, still, sunlit, fresh water. Local breeding preferences of the two varieties in one area are often reversed in another nearby area. Both varieties breed readily at low altitudes but *Anopheles punctulatus punctulatus* is the more important mosquito at higher altitudes (up to 3,500 ft). However, it has not been found on the mainland of Australia, whereas *Anopheles punctulatus moluccensis* has been found in almost all the areas north of latitude 20° S. in which occasional outbreaks of malaria have occurred. Adult females of both varieties rarely rest indoors except when engorged, but field experiments in Papuan villages suggest that a considerable reduction in malaria incidence can be obtained by the treatment of hut interiors with D.D.T.

Naturally infected adults of *Anopheles subpictus*, *Anopheles bancrofti*, *Anopheles lungae* and *Anopheles amictus* (once at Cairns, 1942) have been captured on rare occasions, but all are of minor importance in malaria transmission in this region.

No naturally infected female of *Anopheles annulipes*, the most common and widespread anopheline on the Australian mainland, has been caught. The circumstances of the outbreak of *vivax* malaria at Sellheim (80 miles west of Townsville) in 1943 indicated that *Anopheles annulipes* was the vector, and it was probably responsible for the rare cases reported further south.

SPECIES OF PARASITE

In Melanesia all species of parasite are found, the proportions varying in different areas and at different seasons. Amongst the Australian forces the majority of cases occurring during military campaigns were due to

Plasmodium falciparum. Many of the same soldiers have also been infected with *Plasmodium vivax*. Infection with *Plasmodium malariae* is rather uncommon and *Plasmodium ovale* has been recognized on only a few occasions.

The only definite evidence of different strains of parasite is the recent discovery in the Wewak area of a strain of *Plasmodium falciparum* which is relatively resistant to atebrin.

In Australia, all recent cases of locally contracted malaria have been benign tertian. In earlier outbreaks in Northern Territory and in North Queensland both *falciparum* and *vivax* malaria occurred. *Plasmodium malariae* has been reported once from Northern Territory. There has been no increase of malaria in Australia due to troop movements in the recent war.

FACILITIES FOR INVESTIGATIONS

The anti-malarial organization of the Australian Army has been disbanded concurrently with the demobilization of the Army. Entomologists trained in malaria investigations have returned to various State Departments of Agriculture and to different branches of the Council for Scientific and Industrial Research. A nucleus of entomologists and parasitologists trained in anti-malarial investigations will continue work on the same lines at the Sydney School of Public Health and Tropical Medicine.

There are two malaria control officers on the staff of the Department of Health of the Administration of New Guinea.

AIRCRAFT AND THE SPREAD OF INSECT-TRANSMITTED DISEASES

By G. M. FINDLAY

DURING the war, the spread of mosquito-transmitted diseases, more especially by air, was a sanitary problem of very considerable importance. From 1940 till the reopening of the Mediterranean to the Allies, all aircraft destined for the Middle East or India had to fly across Africa through the yellow fever zone. Even after the collapse of Italy the trans-African route was largely used by the U.S.A.A.F. for reaching China and the Far East.

Two closely linked problems had to be considered—

(1) the spread of yellow fever to non-endemic areas ;
(2) the carriage of *Anopheles gambiae*, the most important vector of West African malaria, to South America and other countries where it does not at present exist.

In order to grapple with these questions inter-allied Mosquito Control Boards were set up and very extensive drainage schemes were undertaken at crucial points. Now with the coming of peace the Captains and the Kings of mosquito control have departed, leaving many of their drainage schemes unfinished. Local governments, however, remain, and with inadequate resources both in money and men are left to deal with the sanitary control of aerodromes and aeroplanes. Peace, therefore, has raised a number of problems which it might be well if this conference could discuss and on which it would appear to be competent to express an authoritative opinion.

THE SPREAD OF YELLOW FEVER

Yellow fever may be transmitted by—

(1) Persons carrying the virus of yellow fever in the blood.
(2) Mosquitoes infected with yellow fever virus.

THE SPREAD OF YELLOW FEVER IN THE PAST

It is uncertain whether yellow fever arose in the Old or New World or whether it originated in Gondwanaland before Africa and South America drifted apart probably early in the Cretaceous age. Historically *Aëdes aegypti* must have reached the New World from the Old before 1647 when an epidemic of what was almost certain Aëdes-transmitted yellow fever ravaged the Caribbean area. During the eighteenth and nineteenth centuries yellow fever spread by Aëdes-infected ships from African to New World ports, or from African or West Indian ports to Gibraltar, Spain and Portugal and in one instance to Swansea. A recent example of ship-transmitted yellow fever is provided by the history of the S.S. *Sea Rambler*.

The spread of yellow fever to-day

Increasing speed of transport has altered the possibilities of spread—

(1) Motor buses have replaced the camel-caravan and pedestrian traffic.

(2) Aeroplanes. Even in 1944 it was possible to fly non-stop to the U.K. from West Africa in sixteen hours or to reach India from West Africa in under twenty-four hours. With jet-propelled planes cruising speeds of well over 400 m.p.h. will be common. Immunization has cut down the risk of carrying an infected person by air. There is, however, a possibility of an infected person being carried by boat from Kilindini Harbour, Mombasa to India with the virus of yellow fever still in his blood stream. Dhow traffic in the Red Sea and Indian Ocean is not dangerous despite the number of Aëdes carried on board.

Yellow fever during the war

In 1940 an enormous outbreak occurred in the Nuba Mountains in Kordofan, Anglo-Egyptian Sudan. Outbreaks also occurred in Portuguese and Spanish Guinea while isolated cases were recorded from the south eastern Sudan, Kenya, West Africa and the Belgian Congo. Recent surveys for immune bodies show that yellow fever must have occurred recently in all the four British West African Colonies while the endemic area now extends from the Atlantic coast to the Red Sea and from the southern border of the Sahara to Northern Rhodesia.

Monkeys with immune bodies have been found from the Gambia to the Belgian Congo as well as in the Sudan and Kenya.

The spread of malaria

There is historical evidence that malaria was introduced into North America by the Spaniards in the sixteenth century.

Anopheles gambiae did not reach the New World till 1930, following increase in the rapidity of transport. Importation again occurred in 1943. *Anopheles gambiae* is particularly dangerous because of its fondness for domestic breeding and its catholic tastes in breeding places.

OTHER INSECT VECTORS

Tsetse flies have already been carried by plane from West Africa to South America. It is possible that dengue may be spread by aeroplane : there is a possibility that all strains of dengue do not cross-immunize. Mosquito-transmitted encephalitides are also a danger.

CONTROL MEASURES AGAINST THE SPREAD OF YELLOW FEVER AND MALARIA

The following measures are essential :—

1. Immunization against yellow fever with living vaccine of passengers, crew and all aerodrome staff ; exemptions on the grounds of essential war services should now be abolished. Questions of forged immunization

certificates and adequate inspection of certificates require immediate consideration.

2. Storage and control of yellow fever vaccine. Adequate supplies of active vaccine should be kept in each country with suitable means of transporting it : periodical retesting of vaccine is essential.

3. Mosquito control of aerodromes. (*a*) Correct construction—e.g. flat roofs undesirable ; (*b*) drainage ; (*c*) spraying with D.D.T. of aeroplane buildings, mosquito proof gauze, a snare and a delusion ; (*d*) spraying of surrounding dwellings ; (*e*) suppressive anti-malarial drugs for aerodrome employees and for inhabitants of surrounding villages ; (*f*) removal of bush suitable for monkeys.

4. Treatment of aeroplanes with D.D.T. : spraying when *in flight* with pyrethrum.

5. Designers of aircraft have not taken into consideration (*a*) dead spaces in planes where mosquitoes can shelter from sprays ; (*b*) the construction of a ' tracheal system ' in aeroplanes for spraying in flight.

The administrative measures outlined above are far more than any Colonial Government can undertake on what is primarily a problem of international concern. It is also most desirable that control measures should be standardized from one country to another.

It is suggested that this meeting should urge the setting up of a permanent trained staff under U.N.O. for (*a*) the supervision of yellow fever immunization and the control of the vaccine ; (*b*) the mosquito control of aerodromes.

MEDICAL RESEARCH AND THE OUTSTANDING PROBLEM OF MEDICAL SCIENCE IN NEW ZEALAND

By Professor C. E. HERCUS, D.S.O., O.B.E., M.D., B.D.S., D.P.H.
(Dean of the Medical Faculty at Otago University, Dunedin)

THE purpose of this statement is to describe the organization of medical research in New Zealand. Until the Health Act of 1920 conferred research functions upon the New Zealand Department of Health, medical research was confined to the National School of Medicine in the University of Otago situated in the town of Dunedin. This School, established in 1874, has always maintained the tradition that teaching and research are inseparable. The researches carried out in the clinical and laboratory departments were financed in the main from university funds which come in part from government sources and in part from grants in aid from the New Zealand Institute. In 1937 a Medical Research Committee of the Department of Health was established with the Director of the Department of Health as chairman and with representatives appointed by the Minister of Health from the Faculty of Medicine, the British Medical Association New Zealand branch, and the Departments of Scientific and Industrial Research and of Agriculture. This committee, later known as the Medical Research Council, decided to promote research by making grants from year to year to long term research projects of particular New Zealand interest. Following the precedent of Britain, committees of persons with expert knowledge were set up to advise the Council and assist in the conduct of each branch of research. Initially six committees were set up to investigate nutrition, thyroid disorders, hydatid disease, tuberculosis, obstetrics and dental disease. Later three more committees were added, viz., clinical medicine, neurophysiology and neuropathology, and virus and immunological research. In all but two of these research projects the work has been concentrated in the Medical School. Provisions for the Council's work is made by an annual grant under the vote of the Department of Health. In 1945 this grant amounted to £12,000. The Council is not a statutory body, has no executive officers of its own and is not empowered to receive and administer private funds. Despite these obvious disadvantages the work has progressed smoothly and no reasonable request for funds has been refused.

In addition to the research carried out by the University and the Department of Health, two other sources of finance are available :—

(i) The Travis Research Fund established in 1920 by W. H. Travis of Christchurch with a bequest of £40,000 to assist scientific investigation in New Zealand into cancer and phthisis. Until 1938 the trustees devoted the income to developing radiological research in Canterbury College and the Christchurch Hospital. In 1939 they decided to support a long term laboratory research into the

biochemistry of the tubercle bacillus and in that year they made a capital grant and an annual grant of £1,750 for an initial period of seven years to develop this work. Associate Professor Edson, a one-time Beit Memorial Scholar, has been in charge of the work since its inception. He is a co-opted member of the Medical Research Council and of the Tuberculosis Committee of the Council.

(ii) In 1924 the New Zealand branch of the British Empire Cancer Campaign was established in New Zealand. The work has included statistical, clinical and laboratory research into cancer. In 1930 it established a laboratory of Cancer Research in the Medical School under the direction of Dr Andrew Begg, a previous Research Fellow of the British Empire Cancer Campaign. But for an interruption during the present war this work has been carried out continuously in close co-operation with the Mill Hill Laboratory where Dr Begg is at present working. This Society has also supported radiological research in Canterbury College, Christchurch. Sir James Elliott, the President of the Society, is a member of the Medical Research Council which also makes an annual grant to support a Physical Research Laboratory.

NEW ZEALAND'S OUTSTANDING PROBLEM OF MEDICAL SCIENCE

One of the outstanding medical problems of the New Zealand environment is that posed by the high incidence of thyroid disease, both of simple endemic goitre and of hyperthyroidism. The research work on thyroid problems was at first directed to the problems of etiology and prophylaxis. No part of New Zealand is goitre free and a notable deficiency of dietary iodine intake is present in all parts of New Zealand as compared with the Pacific islands of Samoa, Fiji, Abaiang, and the Solomons, where thyroid derangement is almost unknown. The most notable development in the war years has been the adoption as the official prophylactic measure of iodized salt containing about one part of potassium iodine per 20,000 parts of salt which is calculated to bring the New Zealand intake to the level obtaining in the goitre free region of Samoa.

The main remaining defect of the prophylaxis is that the use of iodized salt is optional, which leaves some part of the population unprotected. A notable reduction in the incidence of thyroid enlargement in school children is already apparent and the Thyroid Research Committee is confident that the prophylaxis will be effective.

Since 1939 the Thyroid Research Committee has devoted its resources almost entirely to the study of positive goitrogenic agents beginning with the study of the thyroid enlargement produced by feeding brassica seeds to rats. The conclusion was reached that the positive agent in the seeds inhibited thyroxine synthesis in the thyroid gland and that the resulting thyroid enlargement was produced by the secretion of thyrotropic hormone by the pituitary in response to falling blood thyroxine concentration. Chemical studies led to the discovery of a thiourea-like substance in the

brassica seeds and so to the discovery that thiourea and its derivatives inhibited thyroxine synthesis. The trial of thiourea derivatives for the control of symptoms resulting from excessive thyroxine was proposed by the local research workers in 1942 and was adopted in the programme of the New Zealand Medical Research Council for 1943. The publications of MacKenzie and MacKenzie and of Astwood and co-workers appearing in 1943 had anticipated the publication of the New Zealand research workers' results.

The clinical trials begun in 1943 were continuing, one of the aims being the evaluation of the relative advantages of thiourea, thiouracil and methyl-thiouracil. Apart from the confirmation of the now widely known fact that such drugs controlled hyperthyroid symptoms the most notable outcome was that after a period in which hyperthyroid symptoms were controlled, the drug could be withdrawn without relapse. This observation was of great significance in relation to the pathology of hyperthyroidism since it showed that no irreparable lesion was present but that the disease was rather a functional derangement which could be restored to normal equilibrium by a temporary interruption of the excessive thyroid secretion.

The other unsolved problem of goitre in New Zealand, one that was emphasized by the extraordinarily high incidence of hyperthyroidism was that of the etiology of this condition. Although no progress had been made in this direction the Thyroid Research group was hopeful that the utilization of iodized salt would result in a reduction in hyperthyroidism *pari passu* with that in simple goitre.

CLINICAL RESEARCH IN SOUTH AFRICA

By Professor S. F. Oosthuizen,
M.D., M.R.C.P.Ed., D.M.R.Lond., F.C.C.P.

PRESENT POSITION

There is no need to stress the importance of medical education being permeated with the spirit of research, as opinion cannot be divided about this fact. It is also fully recognized in South Africa that it is impossible for a medical school to build up a sound reputation, and earn a rightful place in a scientific world, without promoting adequate incentive and opportunity for research.

Up to the present, clinical research has been sadly neglected in South Africa, but there are many reasons for this. To mention but a few :—

(*a*) *Shortage of funds.* There has been in the past a striking shortage of bursaries, grants and salaries for research workers and laboratory assistants.

(*b*) *Prospects.* Prospects for clinical research workers have been very uncertain, and there has been hardly any opportunity for a career in clinical research. Most of the clinical research up to the present has been done by recently qualified medical graduates working for higher qualifications.

(*c*) *Teaching, administrative duties and economy.* Clinical teachers have been overwhelmed by teaching and administrative duties when full-time, and occupied most of their time with earning a living when part-time. These facts have certainly not served to enhance the cause of research, and there has thus also hardly been any time for reflection upon the results. The energy required to translate initiative into action, has been stifled from the beginning. It has been generally accepted that a limited amount of teaching acts as a valuable stimulus for research, but that excessive teaching is detrimental to the cause of research.

(*d*) *Lack of accommodation.* Accommodation for clinical research is sadly lacking in most South African medical schools. At the Cape Town University, urgent representations have already been made to the Senate to go into the matter. The University of the Witwatersrand, Johannesburg, similarly lacks accommodation for clinical research. The Medical School of the Pretoria University is slightly better off in having a newly erected clinical building, decentralized from the teaching hospital, but easily accessible from the wards. The latter school has been fortunate in having gained from the experiences of her sister universities in being the youngest member of the family.

(*e*) *Importance of training men for medical practice.* The primary duty of most medical schools is the training of men to practise medicine. Most universities are, however, fully aware of the fact that intellectual sterility is almost inevitable if such training is not permeated by the spirit of research. In South Africa, there has been up to the present time a tendency to place the emphasis on the former, particularly in view of the shortage of men to treat patients. A new era is, however, rapidly dawning and a change in the present set-up may be confidently expected in the not too distant future.

(*f*) *Distance.* The great distance between medical schools in South Africa and those abroad has led to a certain degree of scientific isolation, which has not been to the advantage of clinical research.

BODIES INTERESTED IN MEDICAL RESEARCH

The medical schools. There are three medical schools in South Africa, viz. those of the Universities of Cape Town, Witwatersrand and Pretoria, the former being the oldest and the latter the youngest. As already indicated, clinical research so far has been neglected mainly as the result of lack of funds and accommodation.

The South African Institute for Medical Research. In a paper entitled 'Medical Research in South Africa,' before the Conference, the Director of this Institute, Dr E. H. Cluver, has given a good résumé of the activities of the Institute.

The Central Government. The Public Health Act requires the Department of Public Health to promote or carry out research on humans. This Department makes annual grants to the South African Institute for Medical Research (S.A.I.M.R.) and also directly undertakes certain researches.

The Council of Scientific and Industrial Research. The Medical Research Committee (M.R.C.) of the C.S.I.R. acts as an advisory body to the C.S.I.R., and is endowed with the responsibility of promoting research. This Committee is purely an advisory body, and has no executive powers or funds. It has the power to appoint Sub-Committees, like the Dental Sub-Committee, to report back on certain specific problems.

There is no direct representation on this Committee, but at present it does include representatives from the three medical schools, the S.A.I.M.R., the Medical Council, the Medical Association of South Africa, the Department of Public Health, and the Medical Directorate of the Army. The President or the Vice-President of the C.S.I.R. occupies the Chair.

There is at present no independent Medical Research Council in South Africa, and the Medical Research Committee is a purely advisory body to the C.S.I.R. on medical research problems. The appointment of a Medical Director, to direct and organize research, and distribute the funds, is envisaged.

The Medical Research Committee has recommended that a sum of £35,000 be made available for research fellowships, bursaries, major equipment, etc., for 1947. No funds are to be spent on buildings and accommodation, which must inevitably remain the responsibility of the respective hospital boards and universities. A resolution, urging these bodies to provide for adequate accommodation for clinical research, has been passed by the Medical Research Committee.

A few examples of research done in South Africa

Dr E. H. Cluver has indicated in his paper on 'Medical Research in South Africa' that some valuable work has already been done in South Africa. It must, however, be stressed that clinical research has not yet received the attention it merits, and notwithstanding the outstanding work which has been done in isolated instances, a concerted, co-ordinated approach has not been launched. It is impossible to include all the names of outstanding research workers in South Africa, but merely to illustrate that valuable contributions to medical science have been made, a few names have been chosen :

(*a*) *Professor R. Goetz*, Associate Professor of Surgery of the University of Cape Town, on peripheral vascular diseases.
(*b*) *Professor J. van Roojen*, Research Professor of Radiology of the University of Cape Town, on the treatment of cancer by means of radiations.
(*c*) *The Miners' Phthisis Medical Bureau in conjunction with the S.A.I.M.R.*, on silicosis with particular reference to the contributions of *Professor A. Sutherland Strachan* and *Dr F. W. Simson.*
(*d*) *Dr A. Porter*, on bilharziasis.
(*e*) *Dr de Meillon*, on malaria.
(*f*) *The Gillman Brothers*, of the University of the Witwatersrand, on liver disease.
(*g*) *Professor J. F. Brock*, of the University of Cape Town, on problems of nutrition.
(*h*) *Professor J. T. Irving*, of the University of Cape Town, on dental disease.
(*i*) *Professor P. Pyper*, of the University of Pretoria, is a giant in the field of medical research in South Africa, and he has probably contributed more than any other South African medical scientist.

There are many other names which cannot be included in view of lack of space, and this present list is thus far from complete. This modest list is intended to illustrate that there is very fertile soil in South Africa.

SUGGESTIONS FOR THE FUTURE

(*a*) *The worker.* The success of any research scheme must, to a large extent, depend on the quality of the research worker : a fact which is fully accepted by the M.R.C. of the C.S.I.R. The man with an idea should therefore be the main aim of bodies responsible for the promotion of clinical research.

If sufficient competent research workers are not available, approved workers should be trained to carry out research, a project which might be undertaken in South Africa or overseas.

Where men of outstanding ability require an institution for the furthering of their work, such institutions should be provided and established around the man.

(*b*) *Removing difficulties clinical research workers have to face.* As already indicated, there are various reasons why clinical research has been neglected in the past. These will be dealt with under appropriate headings. It is desirable that universities, and other bodies endowed with the responsibility

of promoting research, should attempt to limit the amount of teaching and administrative duties as far as possible to overcome some of the difficulties. This policy will give the clinical teacher more time to devote to research. The M.R.C. of the C.S.I.R. recognizes this, and allows only six, with a maximum of nine, teaching hours per week.

(*c*) *Overseas visits.* Visits to overseas medical institutions, for a period of not less than six months, for the purpose of approved study, travel, and prowling, will be of great benefit to clinical teachers, and those interested in clinical research. In many instances new ideas will be born, while in others an unsolved problem will be approached from a different point of view after consultation with authorities in a particular field.

(*d*) *Regular visits to South Africa of eminent scientists from abroad.* Such a system of movement is highly desirable and long overdue. The idea should not be that these visitors conduct a series of lecture tours, but rather to contact workers in South Africa and stimulate them with their presence and ideas. A scheme might quite easily be evolved by the C.S.I.R. in conjunction with the medical schools and the South African Medical Association, to make such visits possible.

(*e*) *Clinical research chairs.* Research workers of outstanding ability might be offered clinical research chairs. A minimum of teaching should be allowed, but most of the time should be devoted to research. It might even be possible to evolve a scheme whereby the universities and the C.S.I.R. share the financial responsibility. These chairs should preferably be created for the man and should automatically cease when the holder retires.

(*f*) *Funds.* There should be adequate funds for research fellowships, bursaries and grants. The M.R.C. of the C.S.I.R. has recommended to the C.S.I.R. that the sum of £35,000 be made available for clinical research and equipment, for 1947. It is hoped that this financial aid will help to remove some of the financial reasons responsible for the present lack of clinical research.

(*g*) *Type of research.* Inspired as well as directed research should be allowed, and this has already been accepted in principle by the M.R.C. of the C.S.I.R. No matter how small the immediate advantage to be gained from unfettered research might be, it should nevertheless be encouraged.

South Africa with its climatic, racial and economic problems provides a veritable 'natural laboratory' for research, unsurpassed anywhere in the world. There are the problems of sub-tropical regions, climate, altitude, and above all those of racial differences. It is well known that the incidence of diseases like peptic ulcer, pernicious anaemia, cancer and essential hypertension is vastly different in the Bantu as compared with the European. A study into this might not only be of great benefit to South Africa, but might also contribute to the solution of problems of universal importance. Ample opportunities also exist to study problems of nutrition, parasitic diseases like malaria, bilharziasis and echinococcus disease, fungus diseases like actinomycosis, blastomycosis, histoplasmosis and sporotrichosis, to mention but a few.

(*h*) *Accommodation.* Accommodation should be provided by the respective hospital boards and universities. Wherever possible, clinical research

workers should be working on the precincts of teaching hospitals. Where institutes for clinical research are established, the principle of decentralization with easy accessibility should be applied. As previously stated, the M.R.C. of the C.S.I.R. has already passed a resolution urging university authorities and hospital boards to provide, as soon as possible, adequate research accommodation.

(*i*) *Commonwealth Medical Liaison Committee.* The establishment of such a Committee, based on a gentleman's agreement, must hold obvious advantages for the United Kingdom as well as the Dominions, India and the Colonies.

This committee should include :

(i) A central organization with headquarters in London, with one or two medical liaison officers common to all the members of the Empire.
(ii) One or two United Kingdom medical representatives.
(iii) One or two representatives for each Dominion, and also one for India and another for the Colonies.
(iv) A United States medical man as observer.

Problems can be sent by the various representatives to the headquarters in London, and the liaison medical officers, in consultation with the United Kingdom representative, could decide on the course to be adopted in each instance.

Problems of outstanding importance may indicate a conference, to which the various members of the Committee should be invited.

Such an arrangement will lead to more fruitful co-operation between the various countries mentioned above.

MORNING SUBJECT (c)

DISCUSSION OF THE PRESENT STATE OF THE SCIENCE OF NUTRITION WITH PARTICULAR REFERENCE TO THE SPECIAL PROBLEMS OF THE EMPIRE, INCLUDING THE NUTRITIONAL STATUS OF THE INDIGENOUS PEOPLES OF THE COLONIES

Steering Group

Chairman—Professor R. A. Peters, F.R.S.

Recorder—Dr B. S. Platt

Dr E. H. Cluver
Professor J. B. Collip, F.R.S.
Professor C. E. Hercus
Mr A. Glendon Hill
Mr H. R. Marston
Sir Edward Mellanby, F.R.S.
Colonel Sir S. S. Sokhey

Report

The discussion opened by giving opportunities to delegates to describe the nutritional problem in several parts of the Empire with special reference to indigenous populations. The problem was widespread and becoming more acute annually, on account of the general failure of agricultural output to keep pace with the growth of population. It was a problem affecting the whole range of economic and social policy. Whilst the scientist might propose remedies and allot priorities to various remedial measures, responsibility ultimately fell on the general administration. The need for administrators having a due awareness of the nutritional needs of indigenous peoples, at all levels of Colonial government, was warmly expressed.

Malnutrition, due especially to lack of protective foodstuffs, is responsible for the heavy incidence of many diseases, and for low levels of efficiency and general unemployability. It was revealed that in South Africa out of a population of 11,000,000 Africans, unemployability, due mainly to malnutrition, made it impossible to recruit the 250,000 men required for the mines. When certain new mines were opened, at least half of the African workers would have to be recruited from outside the Union.

The Conference expressed sympathy for the view that ultimate economies in expenditure on hospitals and clinics could be effected by heavier outlays on measures to improve nutritional standards. In South Africa a tuberculosis clinic cost about £100,000 with an annual expenditure of £20,000. The incidence of tuberculosis, however, was proportional to the degree of malnutrition, treatment of which should have general priority.

In discussing remedies, the Conference examined first short- then long-term measures. As to the former it was strongly emphasized that there were few cases of malnutrition that could not be cured with synthetic productions already available in large quantities in industrial countries. The use of such methods turned largely upon methods of transport and clinical administration. The application of known principles of food technology offered fruitful short-term possibilities. The increased use of yeast as a protective foodstuff, the introduction of iodine into salt, improved

milling of rice, the inclusion of iron and calcium into cereal foods, the drying of fruit and vegetables, were all technical methods capable of widespread application in a comparatively short period.

As to longer term measures, several speakers were emphatic in urging that unless such were undertaken, human society would find its own adjustment through the ruthless elimination of mouths that could not be fed.

Among the agricultural possibilities the following were explored: (a) That the biggest increase in production could be secured by the use of fertilizers which were comparatively unknown to the indigenous peoples of the Empire. (b) That more plant surveys and a greater number of trained plant geneticists were seriously needed. (c) That the fisheries of the tropics were not so fruitful as those of northern waters. The delegates from the West Indies and Hong Kong pointed out, however, that much might be done by way of improved fishery engineering to assist the primitive fisherman in providing more protein foods for local populations. Concrete proposals concerning Empire fisheries were to be further discussed among delegates concerned with these problems both during the Royal Society Conference and under the auspices of the Official Conference to follow.

Although both Africa and India contained vast herds of cattle, the number available annually for slaughter was small. This situation could not be improved without the breeding of strains better able to resist tick-borne and other diseases, and the more effective handling of the tsetse problem. In Africa the need to protect cattle by shutting them up at night was a great drawback, which required particular attention. In India improved animal husbandry depended largely on controlled breeding which, in turn, could not be applied without overcoming strong psychological and cultural resistances.

Notes

1. See the recommendations emerging from the evening discussion on 'The Role of the Village Pond in the Rural Economy of India.'
2. See the recommendations on subject (a).
3. See the recommendations on subject (j).

General statement

The Conference recognizes that the improvement of the nutritional status of the peoples of the Commonwealth is a part of general social and economic policy in the territories concerned. It urges the necessity for developing at all levels of Colonial government a proper awareness of the nutritional needs of the indigenous peoples.

The Conference strongly supports the need for integrating the efforts of producer, consumer, technical and administrative personnel in effecting improvements in nutrition. In this connexion the suggestion put forward at the first session of the Conference of the Food and Agriculture Organization for the achievement of such integration is welcomed.

The Conference agreed upon the evidence of malnutrition in the Empire, both as to quantity and quality, and urges that measures should be applied immediately for the improvement of the present position.

Among such measures the Conference recommends the following :—

Recommendations

1. Immediate therapy of vitamin deficiency diseases, particularly B.1 for beri-beri in Malaya and Hong Kong, iodine in goitrous areas in Nigeria, calcium and vitamin D in areas where rickets occur in the Gold Coast, iron where anaemia is common, especially in British Guiana.
2. The introduction into the diet of indigenous peoples of nutritional supplements, such as iodine, calcium, iron, etc. where found necessary.
3. Improved methods of storing, processing and distributing foodstuffs, such as better methods of milling wheat and maize, the parboiling of rice, the drying of fish, fruit and vegetables. The Conference urges the need for more food technologists in this connexion.
4. Increased production of the ' protective foods ' through :—
   (a) the control of livestock diseases ; improved animal husbandry and animal breeding, especially of local strains, with the object both of increasing the productivity of the native pastoralist's herds and of developing dairy types suited for use in native mixed farming areas.
   (b) increased and improved fishing operations with the following general objectives :—
      (i) fishery exploration and fish catching (fishery engineering) ;
      (ii) fish processing and technology ;
      (iii) fishery biology and hydrography ;
      (iv) development of great lake fisheries together with fish culture in fresh and brackish waters.
5. Increased food production generally by :—
   (a) the greater use of fertilizers.
   (b) the extension of plant breeding. More plant surveys and an increase in the number of trained plant breeders are urgently required for this purpose, particularly in the African Continent.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr G. C. L. Bertram

The science of nutrition, the feeding of the people, may be considerd to have grown to maturity over one half of its range while the other half has remained in its infancy. There is now a great deal of knowledge and research on the needs and metabolism of the individual, on the clinical signs of deficiency, and on the incidence of dietary poverty throughout the world. All this is as it should be ; first we must have the basic facts as they concern individuals. The science of nutrition is now passing beyond this descriptive phase and has found need to move into the phase of application.

So far there has been such concentration on the nutrition of the individual that there has been some neglect of the wider problem of the feeding of our species as a whole, and the arranging that this shall be done without permanent and serious damage to the environment. Here the science of nutrition borders on that of ecology. For the long term feeding of the species there is need to acquire what may be termed a budgetary outlook, and then effort must be expended on the suitable control of the individual factors which together make up the balance sheet.

At any particular date the nutrition of the species is the sum of individual diets, which is balanced by the total availability of supplies. The result is evident clinically. In practice, any estimation of the total food available to a population is extremely difficult.

When time is included in our consideration, the nutrition of our species can be viewed in its most important aspect. At once the assessment and handling of the factors involved assume formidable proportions. To-day we cannot even assert that in the time of our children and grandchildren the whole, or even a large proportion, of our species will be adequately fed. This is because it is quite clear that at present mankind is out of adjustment with the biological environment from the point of view of the sustained yield of foodstuffs, and of materials derived from the annual growth of plants and animals. In fact, the budget is only balanced by a wangle now and this process can scarcely be long continued.

Adequate future nourishment depends upon the year to year result of an unceasing conflict between a variety of important factors or trends. These factors vary in their incidence and their relative rate of action. Several of the factors are accelerative in action and accumulative in effect, agricultural education and land degradation for instance. Most of the factors are subject to our ultimate control. The advantages of the increase of supplies, by means of improved agricultural techniques, the cultivation or irrigation of new lands, varietal selection and so on, are in conflict with the combined effect of an unprecedented increase of human numbers on the

world scale and the processes of land degradation in the form of soil erosion, falling fertility, overgrazing, overfishing and a whole host of others. All these factors must somehow, I suggest, be assessed numerically so that they may be properly equated and integrated. Then the progress of the conflict may be viewed in its entirety so to allow exceptional effort where necessary in the control of the rate of action of particular factors. Real assessment and the integration of factors must become the basis of policy. This great section of the science of applied nutrition so far has been a very poor sister, scarcely welcome in the homes of the orthodox. At present we know how the individual should be nourished, but we are far from knowing, or arranging, that the nutrition of the race shall be adequate a few decades from now.

I should like to refer to one further aspect. It is quite obvious that a satisfactory long-term outcome of the conflict which I have just described requires, by planned effort, the deliberate control of all the factors involved. This necessity is now widely accepted for most of the factors of production, both helpful and unhelpful. But not yet generally accepted is the need for the future control of the factor of requirement. This in reality is directly proportional to human numbers. We cannot escape from the fact that ultimately human numbers must be controlled—best that this should be soon, and by the conscious and collective exercise of the free wills of populations of educated people. It must surely be, that for any chosen standard of nutrition and material well-being, there must be an optimal human population. Of course the optimum, whether world or regional, will alter with changes in total productivity, but at any particular date there must be a particular optimum or optimal range. Departure from the optimum, particularly in the upward direction, is inevitably accompanied by a degree of misery. Few will dispute that some areas of the world have already exceeded the local optimum and suffer, and will continue to suffer, accordingly. Unfortunately there seems usually to be a correlation between present dietary need, lack of purchasing power to help remedy that need, and rapid increase in numbers. Solutions of the problem, on present principles of economics and of philanthropy, are at variance.

Crisis is quite obviously not far ahead. The vigour of present policies must be related to properly assessed factors in the major conflict. It is the relative rates of action of all the factors which matter, for a genuine balancing of the budget of human nutrition in the future.

Dr D. M. Blair

I wish to draw attention to the conflict that may arise between the demands of national economy for the production of a cash food crop of high yield but low nutritive value and the needs of the indigenous peoples for a locally grown cereal food containing the maximum protein, minerals and vitamins.

In Southern Rhodesia the interplay of these factors has had its effect on native nutrition generally in an adverse direction. In the urban areas and areas of European settlement the staple cereal is finely ground white mealie meal which has a poor protein, mineral salts and vitamin content. In such areas cereal supplies are well regulated, starvation is rare but malnutrition is common.

In the rural areas remote from European settlement the African continues to grow his traditional food crops of the millet family. These are often of poor yield but are much better protective foods than white maize meal. Starvation may occur in years of poor rainfall, but the evidence of malnutrition is rare.

It is therefore of the first importance to study the nutritive factor when crops of improved yield are being encouraged and not consider the yield per acre as the chief object.

Mr Afzal Husain

India is grossly short of foods of all description. It is estimated that one-third of the population is underfed, and the food of the greater proportion of the remainder is very ill-balanced, and contains very small proportions of protective foods. We have to increase food production and particularly the production of protective foods. Milk production is very low and consumption averages 5 oz *per capita* per day for the country as a whole. The situation is worse in those parts of the country where intensity of human population is high, such as Bengal and Bihar. In these regions the daily consumption per head is 3 oz. The physique of the people is degenerating as is evident from the figures of body weight. The average human body weight in the Punjab is 150 to 170 lb, it falls to 120 to 150 lb in Western United Provinces and Bombay, and it is only 100 to 120 lb in the Assam, Bengal and Madras. How far can this process go on and how long it is not possible to state. Nor can we say what the consequences of this degeneration will be. This much, however, is evident that the problem needs a very thorough study. Improvement in the standard of nutrition is urgent, and the attack must be all along the line. The method of determining the food requirements on the basis of ' calories ' has done a great deal of harm. It has diverted attention from protective food and focussed it too prominently on cereals, the chief source of carbohydrates and therefore ' calories.' It is doubtful if cereals will continue to supply the world's food requirements, and certainly will not meet the food requirements of the rapidly growing population of India. We must switch over in an increasing degree to crops which give us more food per acre such as potato, sweet potato and cassava, reduce our area under cereals and release land for increased production of ' protective foods.' I am aware of the fact that cassava is not a favourite of the nutrition experts. Surely with the development of food-technology even cassava can be reinforced with a full complement of all types of protective foods, minerals and vitamins.

Another crop of great achievements in China as well as U.S.A. is soya bean. Nutritional experts in India have given their verdict against it. Surely this is not the final sentence !

To solve India's nutritional problem, we must produce more of food per acre, improve the quality of our food in terms of increased production of protective foods and must employ food-technology to give our population as balanced a diet and as cheaply as possible.

Colonel Sir Sahib Singh Sokhey

The whole morning's discussion of the minutae of science of nutrition and the devising of still more complex organizations to go into still more

minutae of research seem very unreal to a worker coming from India. The problem of nutrition as it faces us is very different to what usually concerned a European worker in peacetime. We have a quantitative shortage of food. Of the 75 million odd tons of cereals we need, we produce only about 50 million tons ; we produce no more than 20 million tons of millet for a population of 400 millions, and so on. During recent times we have had very weighty and expensive agricultural commissions which have been very productive of weighty blue books, but have not added to the amount of food produced. We even run an Agricultural Research Council which usually pours several lakhs of rupees down the drain and causes serious shortage of paper by publishing ponderous research reports, but all this expenditure of money, brains and paper yields no more food.

The responsibility of producing more food ultimately rests on the shoulder of the man who owns three-quarters of an acre of land and possesses a bent piece of wood or two to scratch the ground with. To me it seems there is something very seriously wrong with our concept of research. Of course we must work to obtain fundamental knowledge to acquire mastery over the environment in which we live, but research must be realistically harnessed to the problem and responsibility attached to the research workers. Such a realistic approach demands an intimate collaboration among agriculturists, medical men and engineers such as Sir Joseph Barcroft pleaded for, actually to take the responsibility for facing and solving the problem.

FOOD CROPS OF NIGERIAN PEASANT HOLDINGS

By A. G. Beattie
(Director, Agricultural Department, Ibadan, Nigeria.)

The country's geographic expanse and general productivity safeguards against total famine, although seasonal scarcity may assume the character of local famine. But whilst Nigeria may claim quantitative plenty, protein foods are under-produced and qualitative want is general. The cow pea and lima bean, the groundnut, and bambarra groundnut are common domestic legumes, but as in the case of fruits and vegetables, the amount used falls short of dietetic needs.

The staple diet of the masses consists of starchy, bulky foodstuffs ; millet, guinea corn and rice in the north, yams, cassava and maize in the south. Subsidiaries range from bananas, plantains, coco-yams and sweet potatoes to the Hungry rices (*digitaria* and *eleusine* spp.) of hill tribes. Grain beers, and palm wine as well as many herbs are important supplements to diet, and the quality and quantity of cooking oils are generally adequate.

Peasant farming forms the backbone of food production, and though crops and rotations vary with soil and climate, the practice of alternately cultivating and resting the land under natural vegetation is general. Shifting cultivation has served in the past, but as pressure on the land increases this practice alone can lead to rapid soil deterioration. An awakening desire for the products of Europe calls for an expanding volume of export crops, and increasing urban population demands yet more food-stuffs from the farms, whilst in some areas a steady increase in population exerts dangerous pressure on available farmlands. It is obvious that traditional farming must give way to more permanent and intensive agriculture.

Maintenance of fertility on Nigerian holdings is the foremost problem. Many varieties of cow peas and other legumes are used in rotations, but no generally acceptable system of green manuring has been evolved. The only stock owned by the average farmer consists of some poultry and a few goats, sheep or pigs. These are numerically insufficient to supply the manurial requirements of the average holding, and under present conditions intensive management tends to exaggerate the effects of parasites and disease. On the other hand under the ownership of the pastoral Fulani, Nigeria's five to six million cattle lead a nomadic life under conditions of seasonal feast and famine. Their yield in dairy produce and fresh meat is disproportionate to their numbers, and the difficulties of distribution dissipate the contribution they could make towards a more balanced diet. Ranching and marketing conditions could doubtless be greatly improved, but it is in collaboration with peasant farming that cattle can play a decisive rôle. A combination of crop and animal husbandry offers the soundest solution to the pastoral, agricultural and

dietetic problems. The Department of Agriculture has conducted investigations of diverse systems of mixed farming designed to be suitable for adoption on peasant holdings over a wide range of soil and climatic conditions, and results of this work are being tested and demonstrated in numerous Demonstration and Experimental Unit Farms.

The conservatism of the African, the problems of climate and disease and the aftermath of past overfarming may combine to delay the general adoption of improved farming methods, but the country possesses all the resources of a more intensive and stable agriculture, so that a better standard of living and a more balanced diet seems assured to the Nigerian peasant of the future.

THE PRESENT STATE OF THE SCIENCE OF NUTRITION WITH PARTICULAR REFERENCE TO THE SPECIAL PROBLEMS OF THE EMPIRE, INCLUDING THE NUTRITIONAL STATUS OF THE INDIGENOUS PEOPLES OF THE COLONIES

By MURIEL E. BELL, M.D., F.N.Z.I.C.
(Nutritionist to the Department of Health)

THOUGH New Zealand has been handicapped through its small population and the consequent small allocation of funds for research activities, circumstances have given it rather a special interest in nutrition research. Its professor of physiology (Dr John Malcolm) took an early interest in the newly developing subject of nutrition, and his influence was felt not only in medical teaching, but also in the deliberations of the Council of Scientific and Industrial Research, of which he was a foundation member. Furthermore, New Zealand has had since 1911 a university course in domestic science, and while this had the effect of creating an informed and interested section of the community more ready to welcome research activities, it had furthermore a course for a master's degree for which, by reason of the interest and nutritional training of its dean, Professor Elizabeth Gregory, a majority of the candidates took the subject of nutrition. The Physiology Department and the Domestic Science School therefore provided a training ground and a source from which recruits for nutritional research could be obtained.

In respect to infant feeding, the provision by the Plunket Society of funds for the Lady King Scholarship together with the work of its medical adviser has enabled research contributions to be made as to the normal growth curve, haemoglobin levels, etc., of New Zealand infants.

In 1938, when the New Zealand Medical Research Council was constituted, one of the lines of research sponsored by this body was nutrition research, with a committee consisting of Professor Malcolm (chairman), Professor Hercus, Professor Elizabeth Gregory, Dr M. H. Watt, Sir Theodore Rigg and Dr Muriel Bell. Four of these members are residents of Dunedin, where the researches are in progress, the University of Otago providing laboratory facilities in return for a small rent. Monies are provided by Government grant, allocations being made in each year as part of the vote for the activities of the Department of Health. Accommodation has been limited, and has of necessity restricted the programme of work. Then, too, during the war it has not always been possible to obtain the personnel who were required for specific undertakings.

The Nutrition Research Department had scarcely begun before the war broke out, and its activities therefore were directed in no small measure to work of an emergency nature. However, it has also given its attention to some academic problems. Meantime other departments were also

making use of the newly developing chemical means for testing the specific nutrients in food. Arising from the necessity to investigate the value possessed by certain of the specially processed Army foods, assay work by chemists in the various divisions of the D.S.I.R. has added much to our knowledge of the nutritive value of our foods. We feel, however, that there is still need for further work of this nature, for here there is the growing consciousness on the part of the consumer as to the capacity of foods to vary in value, while abroad, there have been developments such as the Labelling of Food Order by the Ministry of Food, and the growth of that internationalism in food planning which has already occasioned a request from our Government to furnish the British Ministry of Food with a complete list of our nutrient potentialities, a list which could be compiled only by using figures obtained elsewhere for foods that might be very different from our own.

To control the researches of this nature and to direct them into channels in which the choice of food grown will have some relationship to its highest nutritional content, a food sub-committee of the D.S.I.R. was formed. On that food sub-committee are representatives of the following divisions of the D.S.I.R. : Wheat Research, Plant Research, Dairy Research, Fruit Research, Dominion (Analytical) Laboratory ; to which are added Professor Gregory and Dr Muriel Bell to act as a liaison with the School of Domestic Science, the Department of Health and the Medical Research Council.

As our country is an exporter of pastoral products, and as the British Ministry of Food now demands a declaration of the vitamin content of the foods it buys, such a committee will function in the interest of the export field as well as of our local consumers. It is the intention of this sub-committee to use whatever new scientific developments it can for increasing our capacity to grow food of better nutritional value. It proposes, by extending its plant breeding activities, to develop yet other strains of wheat, and to make more available to both ends of New Zealand fruits and vegetables which now grow preferentially in one particular location. Chemical investigations are being planned so as to avoid duplication of labour, researches and results are to be pooled, rather then permit waste of substance and time by individual and unrelated efforts.

As with other countries, much that has been done during the war has remained unpublished to date, and it is now hoped that the information collected will be made available through the medium of print.

Collaboration between one department and another has made it possible to get certain advances in train. For example, the Wheat Research Institute has worked hand in hand with the Nutrition Research Department in a plan to improve the nutritional value of flour and bread. The former devised the long-ferment process for permitting the inclusion of wheat germ in bread without impairing the baking quality ; the latter did the animal tests for vitamin content and advised the quantity of germ to add. The W.R.I. devised machinery which could be made locally for making flour of higher extraction. They estimated the vitamin content of the mill streams, selected those with the highest vitamin value, and applied their detacher on a small scale in their own mill, studying the conditions of speed, rate of feeding, rate of outflow to get the maximum effect. When they were ready to apply their experimental work to a large scale mill,

the Department of Health, on the recommendation of the nutrition committee, secured a grant from the Cabinet to enable the W.R.I. to use a commercial mill for trying out this new process, and a commercial bakery for the baking trials of the flour so produced. At each stage the advice of the nutrition committee has been sought as to what proportional increase in vitamin content would be considered desirable, taking into consideration the average food consumption of the less well-paid classes, and the inevitable repercussions on the poultry industry which must occur in a country where pollard forms such a conspicuous part of the fodder for poultry. It is hoped to be able to bring all mills into production of higher extraction flour during the coming year; the millers and bakers have expressed their willingness to co-operate in the scheme. By preparing them in advance, the institution of flour of higher extraction will, we hope, go over smoothly.

The association with the Medical School has given opportunities for applying laboratory techniques to the diagnosis of cases, e.g. estimation of vitamin B_1 in urine, saturation tests for vitamin C status, use of Waring Blendor for making meat into a consistency suitable for feeding allergic infants.

ASSAY WORK

Chemical or biological assays on foods have been fairly numerous; some of the work it is as yet unpublished, some is still in progress; the following list is therefore incomplete.

Apart from the work of the Dominion Analytical Laboratory which is constantly analysing and checking foods, the following indicates the type of work that has been in progress :—

New Zealand Fish: protein, fat, caloric value, thiamin, riboflavin, vitamin A and vitamin D of fish liver oils.
New Zealand breakfast foods: thiamin, phytic acid.
New Zealand butter: vitamins A and D.
Milk: protein, fat, total solids, solids-not-fat, thiamin, riboflavin, nicotinic acid, calcium.
Vegetables: calcium, available calcium, ascorbic acid.
Fruits: ascorbic acid, variety of apples and tomatoes and ascorbic acid content.
Wheat: protein, thiamin.

Units for vitamin assays—This is a matter which encroaches on morning subject (**b**), 'Discussion of measures which might be taken to secure greater uniformity in standards of measurement.'

Trouble is experienced through the difference between the American and the British interpretation of the unit for vitamin A. It is hoped that this will soon be remedied by international agreement.

STUDIES ON NUTRITIONAL STATUS, INCLUDING DIETARY STUDIES ON MAORIS

A series of three dietary studies reported in the 'New Zealand Medical Journal,' 1943 and 1944, have been done partly by the Department of Domestic Science, and partly by the Nutrition Research Department

While our dietary standards for good health are still uncertain, we can do no better than to relate the intake to those standards tentatively adopted as a guide to good nutritional intake. The classes studied were various, but the bigger groups were of basic-wage earners, Maoris and farmers. The studies could with advantage have been extended over a longer period, and have covered greater numbers ; but a more comprehensive study involves much more arithmetical analysis, and we had neither the time nor the staff to undertake the more extensive study. The material that we had gathered was of great use to us when we had rationing quantities to decide, and we then felt the need for more data of this type. Reprints of these studies are available from the Nutrition Research Department.

As far as one can summarize the results, the salient features are as follows :—

Calories—The caloric intake was rarely low. On the average, more calories were consumed than were necessary, but a certain percentage were below the standard adopted. This applied particularly to the Maoris studied, a result which, in our opinion, belied the real state of affairs. Activity being the basis for caloric needs, it is difficult to make an assessment of the needs to an accurate degree. Most of the Maoris were designated as ' bush-workers,' the standards for which occupation were probably higher than the actual caloric expenditure. The standards were presumably collected in a different climate, on a different race ; and moreover, a Maori bush-worker would still be designated as such, even if he were driving a truck. It can be fairly definitely stated that the New Zealand population including the Maoris does not suffer from hunger ; indeed, the criticism levelled at many of its members is that obesity is too common. We regard our standard of living, at any rate as far as calories are concerned, as one of the highest. At the period when the studies were made, namely, prior to the introduction of rationing, there were no food stringencies.

Protein—Again, the intake of protein is rarely insufficient, and the proportion of animal protein usually reaches one-third of the total protein, and is often up to one-half. Choice of meat (or fish, especially in the case of Maoris), in preference to cheese or milk is fairly characteristic, though rationing has somewhat restricted this preference except in the country districts.

Calcium—Owing to the low intake of milk (about which more will be said later), the calcium intake frequently falls below the optimum. This was particularly pronounced in the case of the Maoris, nearly all of the families being on an intake that was below the standard considered desirable. Again it must be pointed out that standards have been assessed from studies on other races and in other climates. However, the Maori has in a short period of a hundred years adopted our way of clothing himself, our way of sending the children to school, but not our way of consuming milk to offset the diminution in the vitamin D that his skin was in the habit of making. At this point it is perhaps not irrelevant to mention that an experiment by Turbott and Rolland on the use of milk in a Maori school indicated an appreciable increase in growth rate compared with that in an adjacent school where no milk was being given. This experiment was done prior to the institution of the milk-in-school scheme.

Iron—This mineral is frequently below the average standard considered desirable. Apart from pathological cases, shortage of this element shows up, as is to be expected from metabolic studies, only in the susceptible groups, viz. children, adolescents, women, especially expectant and nursing mothers. Recent studies on each of these groups show that in a porportion of the subjects an anaemia exists, e.g. in about 12 per cent of expectant mothers, and about 15 per cent of school children, in the groups studied.

Again, the shortage of iron was more notable in the Maori dietaries, about half of the families not getting sufficient iron in their food. No published figures on haemoglobin levels are available, but it is stated by doctors working in hospitals in the Maori areas that low haemoglobin values are frequently encountered.

Iodine—As lack of iodine and the occurrence of endemic goitre is a major medical problem in New Zealand, it will be presented separately.

Cobalt—At times, the suspicion has been expressed that in those areas which are marked by the occurrence of ' bush-sickness ' in animals (due to deficiency of cobalt) human health is suboptimal, or that anaemias of obscure etiology make their appearance, but, though it is understood that some medical work is under way, no report is yet forthcoming to refute or confirm the suspicion.

Fluorine—is dealt with on Page 16.

Vitamins

Vitamin A appears in general to be adequately supplied. In the Maori study, the time of the year was an unfavourable one for vitamin A containing vegetables ; therefore the intake appeared to be suboptimal. Ordinarily, however, the Maoris do not need persuasion to eat their puwha (sowthistle), which is cooked with the meat.

As a rule, the high intake of butter makes it unlikely that vitamin A deficiency would occur. Prior to rationing, the figures for butter consumption per head of the population were the highest in the world. Rare cases of night blindness curable by administration of vitamin A are more to be ascribed to distaste for dairy products than to lack of availability of supplies.

Vitamin B factors are, however, not taken in optimal amounts.

Thiamin (*aneurin*)—According to the most recent standards of the U.S.A. National Research Council, the dietaries of basic-wage earners contained on the average an amount of aneurin sufficient for ordinary needs. The quantity present in the Maori dietaries was however below this level.

Where we have most of our doubt about the dietary in respect of its vitamin B_1 content is in the special groups which are considered to require more, such as in growth, pregnancy and lactation. There is some evidence that aneurin deficiency occasionally manifests itself in the ante-natal clinic.

If we are to judge by excretion levels a group of university students studied by Allen showed rather low aneurin excretion in twenty-four hours by those living in lodgings compared with those living in hostels or at home.

Riboflavin—For studies on Europeans, the same is to be said for riboflavin as for aneurin. To the low intake of milk is principally to be ascribed the subnormal intake compared with the standard, particularly stressed in the Maori studies.

An assessment of the riboflavin status of pregnant women—since this is the type where the low intake is said to result in occasional symptoms of deficiency—is about to commence.

Nicotinic acid—The quantity of nicotinic acid present in the foodstuffs chosen by the New Zealanders studied in this series is practically up to standard. New Zealand conditions favour a consumption of meat in normal times which exceeds that recorded for other countries, and while the offal meats are not generally popular, the nicotinic acid of the dietary yet appears satisfactory. Apart from occasional medical conditions conducive to its occurrence pellagra is not seen in New Zealand.

Vitamin C—It is probable that the intake of vitamin C is on the average sometimes above and sometimes below the requirement. The first state of affairs held in the studies of the basic-wage earners, on whom the survey was made during the tomato season, while with the Maori survey which occurred during the off season for vegetables, there was a deficit.

A few tests have been done on groups of students and nurses. Some showed high values and some low levels of vitamin C in the blood plasma. No very large scale assessment of the degree of tissue saturation with vitamin C has been made, though it has been on our programme.

We have been occupied with tests on the plasma ascorbic acid of personnel in camps during the war, and in keeping with the experience recorded elsewhere, cooking on a scale of the magnitude found in army camps is attended by very great destruction of the vitamin C in the food, reflected in low levels of ascorbic acid in the plasma. The significance of this from the health point of view has still to be defined.

Suffice it to say that we feel uneasy about the standards, and about certain areas where vegetables are not easily grown particularly during the winter, about the intake during pregnancy, lactation and childhood, and about those who live in institutions or eat in restaurants. On the whole the popularity of potatoes and the keeping qualities of Sturmer apples, high in vitamin C, act as safeguards against outspoken vitamin C deficiency, and it is rare to encounter cases of adult scurvy, or scurvy in children.

To vitamin C in infant feeding reference is made elsewhere in this report.

Vitamin D—Leaving out of account at this stage the question of vitamin D for infants, the three dietary surveys showed that, the food intake of vitamin D being very defective, New Zealanders were very dependent on sunlight for a sufficiency of anti-rachitic vitamin. Whether or not this has a relationship to our dental caries problem is uncertain, and will remain uncertain until we know more about what forms of vitamin D and what other factors are necessary for the proper formation and health of enamel, by comparison with those required for bone calcification. The latter process appears to be satisfactory, even when the dietary intake of vitamin D is low, at age periods when rickets has been reported to have a high incidence in U.S.A., from which we conclude that our sunshine record is not without its benefits as a prophylactic against rickets in the four–fifteen year period.

Summarizing the findings arising from these studies, the difference between the errors of the Maori dietary and that of the European is merely one of degree, the Maori showing an exaggeration of our European faults.

With regard to specific foodstuffs, comments will be made on the situation with regard to milk, sugar, vegetables, fruit.

Milk

The average intake of milk in the dietary of the basic-wage earners was 0.7 pint, in that of the Maoris 0.6 pint. According to statistical calculations the average for New Zealand is 0.84 pint. (Figures all for imperial pints.) These quantities are surprisingly low for a pastoral country. They would be lower still if it were not for the provision of school milk.

The milk-in-schools scheme—Half a pint of pasteurized milk is supplied free to school children daily. The Department of Health have wisely stipulated that the milk should be pasteurized ; but in those country districts where pasteurized milk is not obtainable, they permit as an alternative the use of malted milk or of cocoa made with milk on the conditions that school committees see that there is a suitable room and equipment for preparing it. As these conditions are not always fulfilled, school milk is not always available for school children. Moreover, there is in some districts a shortage of liquid milk during the winter months ; in other districts summer drought may curtail sufficient supplies for schools ; and in addition, there are areas where the cold weather in winter time causes the children to refuse to take the milk. However, in spite of these difficulties, the figures continue gradually to advance until over 85 per cent of the school population are now supplied, the numbers in 1944 being :—

pasteurized bottled milk .	222,438	pupils
malted milk . . .	8,234	,,
milk for cocoa . . .	5,029	,,

There is a widespread lack of appreciation of the value of milk, even in pregnancy and lactation. There is no provision of free milk to expectant and nursing mothers, for it is held that it can be afforded under existing wage-rates. There are two chief reasons underlying this attitude to milk in a pastoral country—lack of knowledge as to its value, and dietary habit. New Zealand showed considerable wonderment when it saw American troops ask for milk to drink. In country districts there is often a dislike of milk because they ' see too much of it,' i.e. they associate it with the smell of the cow-yard.

In addition, there is an opinion widely held by dentists that milk encourages the growth of the organisms which are responsible for attacking the teeth. To the author, this would seem to have more validity if there were a demonstrable correlation between the use of milk and the rate of dental caries ; but, in general, nutritionists favour the belief that milk helps in the prevention of dental decay ; and while statistical correlations remain scrappy, it will remain a belief. It is time that one or other of these beliefs was put on a sounder scientific basis.

It may seem odd to hear that supplies of town milk are anything but satisfactory, not only in quality, but also in quantity. The capacity to produce good quality milk in adequate amounts is not lacking, but other types of farming have been more attractive. Disturbed by this situation, the Government in 1943 appointed a Milk Commission to enquire into the causes, and to make recommendations for improving our milk supplies. Arising from their report, a Milk Bill was passed in 1944, setting up a Central Milk Council and local Milk Boards, together with a Milk Marketing Division, centrally situated. Through the latter subsidies are paid by means

of which it is hoped to encourage the proper production, treatment and bottling of milk. There are widespread prejudices against the use of pasteurized milk, while skim milk is frequently regarded as of little value. To overcome both of these prejudices, educational material is distributed by the Department of Health.

Sugar

Rationing has put a brake on sugar comsumption, but prior to its introduction sugar consumption in New Zealand was outdone by that in only one other country, namely Denmark.

The daily average quantity consumed in the homes of the people studied in the dietary surveys was 3 oz. per head. This does not tally with the year-book figures, which put the total quantity used per head per day at $5\frac{1}{2}$ oz., inclusive of confectionery, and inclusive of the relatively small proportion used for beer out of the total quantity imported.

There is no doubt about the popularity of cakes and sweets. Visitors from other countries remark on the frequency with which cake is offered—for morning and afternoon tea and late supper. Nor is there any restraint, in normal times, in the amount offered ; much of the capacity that is inherent in women for decorative art is put into their cake-making, and it is no exaggeration to describe the afternoon tea trolley as an exhibit of variety in shape and colour carrying up to a dozen different plates of cake. To a worthy sense of hospitality there are added pride and rivalry, to keep up this state of affairs. It would not worry a nutritionist if this occurred only on party occasions, but it is far too frequent, and represents one of our worst faults. It is not uncommon to see the regular choice of a series of cakes accompanied by a little bread and butter, or more frequently by scones, on the part of those getting their lunch at cafetarias.

Rationing has done something towards reining in this tendency ; but as soon as sugar can be freely bought, it will, we fear, go on with undiminished vigour.

To a nutritionist who wishes to see a full programme of research work, it is rather a bitter thought that the Government pays annually a subsidy which in 1941 amounted to £240,000 to keep the price of sugar down to 4d. per lb.

Vegetables and fruit

When the dietary studies are compared with those reported from U.S.A., it is seen that less fruit and vegetables are taken in New Zealand. Visitors from abroad remark on the tendency to put a large amount of meat and a small amount of vegetable on the dinner plate.

Apples—The following is what might be termed an experiment in consumer capacity ! Apples are normally exported from New Zealand, but during the war they could not be sent overseas. The Government decided to distribute apples free of cost to the school children (in 1944, there were, during twelve weeks, 103,000 cases of apples given free to school children), while the Internal Marketing Division influenced sales to the public through an advertising campaign, with the result that all the exportable surplus has been consumed within New Zealand, and that, contrary to what might have happened if low prices had been operating, the orchardists have not uprooted their trees.

FOOD CONDITIONS IN WAR TIME

Rationing

The scale of allowances of rationed foods for normal consumers has been :

tea (1942)	. .	2 oz. per week
sugar (1942)	. .	12 oz. per week, with 9 lb./year for jam
butter (1943)	. .	8 oz. per week
(1945)	. .	6 oz. per week, this amount being approximately half the normal average consumption
meat (1944)	. .	1/9d. worth per week, i.e. approximately $2\frac{1}{2}$ lb. carcass weight
(1945)	. .	1/6d. worth Children under five—half ration

Bread was unrationed. Cream—sale prohibited. There has been no rationing of milk (though it is sometimes in short supply in certain areas) ; cheese—unrationed ; potatoes—unrationed, though sometimes in short supply ; tinned foods in very short supply ; fish—unrationed, but sometimes in short supply ; pork—unobtainable ; rabbits—plentiful in some districts ; organ meats, sausages, ham, bacon—all unrationed, but some of them in limited supply ; venison could be obtained in mountainous districts, but transport precluded its appearance in the shops. Oranges—scarce ; similarly, bananas ; cod-liver oil and halibut-liver oil were in short supply at times ; eggs in short supply at times.

Priorities :	For certain medical cases, butter, eggs, meat, etc.	
eggs	. .	For expectant and nursing mothers—6 eggs per week For children under five—3 eggs per week
butter	. .	For workers in certain occupations

Research matters arising from emergency conditions

(i) *The shortage of fish liver oils* necessitated that we should turn to our own resources. Consequently the war years have seen the development of commercial production of (*a*) shark-liver oil fortified with vitamin D, (*b*) groper-liver oil (equal approximately in potency to British halibut-liver oil), (*c*) ling-liver oil, which has about five times the potency of cod-liver oil, and has a very acceptable flavour.

It was furtunate that the foundation for this development had been laid by the researches of Shorland into their vitamin A content, and of Marion Cunningham into their vitamin D value.

Further work on the vitamin D content of New Zealand fish oils has been published by Weeber, whose work is still in progress, as is also that of Shorland in respect to vitamin A.

'*Toxicity*' *of fish liver oils*—Arising from the necessity to see that our oils contained no special toxicity, some work was done by Evelyn Moore, who could produce no more than the symptoms of hypervitaminosis-A in rats by oils from New Zealand fishes. A paper on this subject has been submitted for publication, and a further one by Bell is in the course of preparation.

(ii) *Shortage of oranges*—The entry of Japan into the war marked the beginning of the period of short and irregular supply of oranges. Fortunately, the work of Barbara Johns on the vitamin C content of various New Zealand fruits and vegetables had been in progress for a year, allowing us to get under way a programme for preparing substitutes for orange juice, and for disseminating information through the Press and through such widespread agencies as the Plunket nurses.

Owing to our considerable latitude, with differences in climate, it has been necessary to have a variety of substitutes for orange juice, depending on the district. Our main substitute has been *rose hip syrup*. We hurriedly developed household recipes, tested their value, and publicized the results. Though we encouraged mothers to make supplies, the sugar shortage has limited their scope. We had no supplies of citric acid but we devised household recipes using rhubarb juice which lowers the sugar requirement and raises the palatability. These recipes are published in our local books.

The commercial manufacture of rose hip syrup was instigated. It was initially attended by the difficulties that were experienced elsewhere, difficulties that were increased by the tardiness of delivery of appropriate machinery for maintaining sterility and achieving standard content of vitamin C. However, the firms have surmounted these trials, and are now producing a product which conforms to our requirements, and in respect to its vitamin C content reaches the standard of the British Pharmacopoeia.

Rose hip powder is also being produced on a commercial scale. During the war it was incorporated into jam for the prisoner-of-war parcels. At the end of hostilities it was put to civilian use, being sold either by itself or in a jelly-crystal packet.

The circumstances that the province of Otago has many wild roses from which the fruit can be sent in regular supplies to the Dunedin firms is fortunate, for here, as in Britain, the higher latitude is associated with a higher vitamin content on the whole.

Recipes were also developed and tested for home production of blackcurrant juice. There has been no commercial manufacture of blackcurrant purée. Blackcurrant juice was suitable for older infants.

The use of vegetable water for infant feeding was also instituted—made by cooking, for example, two cups of shredded cabbage, or diced cauliflower, in a cup of boiling water, cooking for ten to twenty minutes, then squeezing out as much of the liquor as possible. This could be added to the feed immediately before use. Made in this way, it could be regarded as equal to one-third the value of orange juice. Its suitability was first ascertained by trying it out at the Plunket Society's Karitane Hospital.

Tomato juice and purée were also used, as was lemon juice. The stability of the lemon juice was first investigated, and as a result of tests, it was decided to recommend its addition just prior to the feed, care being taken not to warm beyond body heat.

The juice of New Zealand grapefruit was also suitable.

(iii) *Armed Forces*—Various investigations were required in connexion with food supplies for the Armed Forces. Mention has already been made of the tests on army personnel for their vitamin C status, and on assays of food.

Sometimes special needs arose, for example in connexion with macrocytic anaemia, which occurred temporarily in certain tropical units, foods which would cure the condition had to be recommended and their production expedited.

The provisioning of expeditions where men were going to live in cold, sunless, southerly islands, without communication with the mainland for a period of a year, was an experiment which met with success, but gave us some anxiety until the first year was over and the men reported that they had been in good health. At that time it was particularly difficult to furnish them with substitutes for oranges.

We were able also to supply the information, needed by men going to warm but barren islands, that tomatoes grown by hydroponics contained vitamin C in usual amounts.

Present state of infant feeding in New Zealand

The feeding of infants is largely in the hands of the Royal New Zealand Society for the Health of Women and Children (Plunket Society), whose nurses supervise about 80 per cent of the total number of babies, first visiting them as soon as the mother has returned from the nursing home. Cases that are making unsatisfactory progress are referred to their own doctor.

Breast feeding is considered the feeding of choice. The breast-fed baby requires constant supervision as it is no uncommon thing to find babies who, by test weighing, are found to be underfed on the breast despite the fact that their behaviour is exemplary and that the mothers are totally unaware that the infants are underfed.

Cod-liver oil and a source of vitamin C are given to the breast-fed infant from the age of two to three weeks and onwards.

Artificial feeding—The routine milk mixtures previously advocated for infants have been strengthened by the addition of more milk, and babies are now fed more according to their length, body-build and individual appetite than according to their age.

Vitamin D is advocated in the form of standardized fish liver oil or as Kariol (a 50 per cent ling-liver oil emulsion with a vitamin D content of 1050 I.U. per oz.). The unitage recommended is that advocated by the British Paediatric Association.

If vitamin D is prescribed in the form of a concentrate instead of the natural oil, the infant is fed according to the Marriott system of feeding and twice the standard number of units of vitamin D is ordered.

The administration of vitamin D is recommended for pre-school children (who are supervized jointly by the Plunket Society and the School Medical Officers) throughout the entire year, a lesser dosage being ordered in summer-time.

Vitamin C is given either as orange juice or as one of the many substitutes recommended by the Nutrition Research Department. The amount advocated has been greatly increased in recent years.

Since 1938, solids have been advocated for both breast-fed and artificially-fed infants from six months onwards.

Plunket Society's Survey of New Zealand Infants—In 1939 the Plunket Society authorized its medical adviser, Dr Helen Deem, to undertake a survey of New Zealand infants.

Eight thousand nine hundred and eighty-four infants, whose birth weights were six lb. and over, and whose ages ranged from two to fifty-two weeks, were weighed nude, and measured and examined critically by the medical adviser and her assistant, and searching enquiries were made to ascertain the exact details of the diets given to the infants.

The objects of the investigation were :—

(*a*) To determine the average weight and length growth curves for New Zealand boys and girls during their first year of life. This had not been done previously.
(*b*) To compare the results obtained with those of other investigators.
(*c*) To establish a growth zone for normal infants.
(*d*) To estimate the nutrition of infants whose health and progress was supervised by the Society's nurses and to endeavour to assign reasons for unsatisfactory findings.

The plotting of the growth curves and the compilation of the growth zone were done by Dr H. Silverstone, M.Sc., Ph.D. Edinburgh (in Statistics).

Results—(i) *The new standard weight curve*—The new smoothed weight curve for age showed that the old standard curve was too low for infants over three months of age and that the existing standard required modification.

(ii) The average weights for age recorded for all cases examined compared favourably with the results of other investigators.

(iii) The nutritional assessment of the infants in relation to their feeding showed convincingly that the nutrition of the breast-fed infants was markedly superior to that of those who were complemented or artificially fed.

(iv) The nutrition of the breast-fed infants under six months of age was more satisfactory than that of the older age group, many of whom were too soft.

(v) It was shown that (*a*) body build, length for age, and appetite were factors requiring more consideration when calculating feeding mixtures for individual infants, (*b*) that underfeeding could be checked by questioning the mothers in detail concerning ' leavings,' feeding times, quantity of food actually taken, and measurements used, (*c*) that factors other than food influenced nutrition.

Conclusion—The significance of the survey findings influenced the teaching of the nurses in training and the practice of those in the field.

Lady King Scholar's survey of New Zealand infants—A survey of the nutritional status of 1,076 New Zealand infants aged six months was conducted by Dr W. E. Henley, Lady King Scholar for the year 1939, whose report was submitted to the university authorities in August, 1944. The results are similar to those reported by Dr Deem in her 1942 Report to the Plunket Society.

Haemoglobin estimations were made for the main series, i.e. infants weighing over $5\frac{1}{2}$ lb. at birth ; the average haemoglobin percentage by the

Hellige method was 85 (12·32 gm./100 c.c.) ; 10·1 per cent showed haemoglobin concentrations between 75 and 80 per cent (11·6 gm./100 c.c.), while the incidence of haemoglobin percentage below 75 was 14·4 per cent.

Radiograms of the wrists of 1,041 infants were reported on by a recognized radiologist who gave his interpretation of 995 satisfactory films. Five cases (i.e. 0·5 per cent) showed changes which could reasonably be interpreted as due to rickets. The birthweight of three of the five was under 5½ lb. Of the two full term infants diagnosed radiologically as rickets, one had never had any form of vitamin D and the other had been fed on a patent food for three months.

Survey of ex-premature infants (birth weights under 5½ lb.).

In 1941 Dr Deem made a nutritional survey of 207 ex-premature infants whose ages ranged from twenty to sixty-three weeks.

Incidence of anaemia—All infants with a haemoglobin of under 75 per cent (11·2 gm./100 c.c.) as estimated by the Hellige method were classified as anaemic. 43·5 per cent of the infants examined were found to be anaemic, and of the non-anaemic, ten, i.e. 8·5 per cent, had been taking medicinal iron for some months prior to their examination. The incidence of anaemia was very definitely more pronounced in the lower than in the higher birth weight groups.

All premature infants resident in the Plunket Society's baby hospitals are now given medicinal iron from the age of four weeks onwards, and arrangements have been made with the Director of Medical Benefits for extended prescriptions for iron to be given free for these infants, the cost to be a charge on the Social Security Fund.

Prevention of rickets—As it is generally agreed that the ex-premature is more prone to develop rickets than the full term infant, an increased dosage of vitamin D in the form of a concentrate is prescribed from two weeks onwards. The Director of Medical Benefits now sanctions extended prescriptions for vitamin D for ex-prematures, and again the cost of the preparations is a charge on the Social Security Fund.

Breast feeding in New Zealand—In order to ascertain the extent and duration of breast-feeding in New Zealand, the records of 9,000 consecutive cases who had been under supervision of the Plunket Nurses were investigated in 1940, according to a definite plan.

The Society's professional advisers were under the impression that the breast feeding position had deteriorated over the war years ; consequently another survey is being conducted at the present time, and the results of an analysis of 4,600 consecutive records have been completed. The results of the survey are tabulated below.

BREAST FEEDING IN NEW ZEALAND

	1939–40 (9000 cases)			1944–45 (4600 cases)		
	breast fed per cent	breast plus complement per cent	artificially fed per cent	breast fed per cent	breast plus complement per cent	artificially fed per cent
first seen	81·0	9·5	9·5	69·0	12·5	18·5
3 months	55·3	16·3	28·4	43·6	16·8	39·6
6 months	30·8	16·5	52·7	20·5	14·3	65·2

An effort is being made to improve the existing position by stimulating interest in breast feeding by medium of Press articles, radio talks and posters, and at a conference held this year between officers of the Plunket Society and the Health Department, ways and means of improving the extent of breast feeding in the maternity hospitals was considered.

Rickets—The statement continues to be made by doctors that rickets frequently occurs among New Zealand infants. Dr Henley's report in 1944 did not lend much support to this contention as far as the city of Auckland was concerned. It might still occur in the other, more southern, districts, however, and therefore the following lines of enquiry were undertaken :

(i) *X-ray of wrists and serum phosphatase tests* in those cases which exhibit the physical signs commonly attributed to rickets, such as knock knees, bow legs, pigeon breast, deformed chest ; the cases being derived from Wellington, Dunedin and Invercargill areas.

(ii) *Histological examination* of the costo-chondral junction of the seventh rib of indiscriminate cases that come to autopsy at the public hospitals, most of them dying of acute infections. This is stated to be a very sensitive test, a statement which can be confirmed from local studies, though it is open to the objection that it may not be an indication of the state of affairs that exists in normal living infants.

It was hoped that more definite evidence as to these selected cases, such as are designated by doctors as rickets, might be adduced by the serum phosphate test, i.e., whether they are to be classified as rickets. Our conclusions to date are that, though the phosphatase test is considered to be the most sensitive test that can be applied to living infants, it is either too insensitive to detect this type of case, or alternatively, there is another condition which simulates rickets but of which the cause is not yet clear. It must be stated that all but a few had been consuming about 250 I.U. or more of vitamin D daily, to which can be added the effect of sunshine, of which New Zealand has a considerable share, even in winter-time. That something of the same kind occurs in Britain—cases which are clinically classified as rickets by the examining doctor, but which do not give radiological evidence in support of the diagnosis—was indicated in the publication ' The Incidence of Rickets in War-time.'

There are cases where some of the stigmata usually ascribed to rickets are associated with a low protein intake ; but those cases of low muscular tone, or of late-development of muscular tone, present a problem as to the underlying causative factor.

It would be of interest to know whether any particular line of enquiry is being pursued elsewhere to clear up some of these points, and whether it would be desirable to assign some particular aspect for enquiry in New Zealand.

We are puzzled by the occurrence of rickets in lambs in certain areas, a condition which can be prevented by a prophylactic injection of a single massive dose of calciferol. It seems strange that this should occur under our climatic conditions, but perhaps it is an expression of the greater rate of growth of lambs compared with human babies, greater need for vitamin D, and lesser intake of vitamin D, and perhaps too of fat for assisting in its passage through the wall of the intestine. These points need elucidation.

DENTAL RESEARCH

The problem of dental caries is fundamentally a nutritional one, but a very complex one. New Zealand could well play a part in studies on dental caries because of its high incidence of dental disease, 96 to 97 per cent of the population being subject to caries, while the statistics among recruits early in the most recent war for the incidence of artificial dentures indicated, even for that comparatively young age group, the prevalence of the habit of neglecting conservative treatment—60 per cent had artificial dentures. Side by side with this high rate, and with a prevailing narrow jaw, we have the fact that a century ago or even less the Maoris had no caries, and had well formed arches. When the Maoris adopted our way of living, they developed dental caries. The question has still to be put on a firmer foundation as to whether this situation arises 'post hoc,' or 'propter hoc.'

There is obviously a weakness of tooth structures in the majority of New Zealand-born persons. Investigations are proceeding on the biological side to see whether this is a general phenomenon among animals that develop here.

Dental caries may be classed as interproximal, gingival, and so on, constituting a series of groups, the etiology of the caries in each of which is probably to be found in a different factor. The thickness and hardness of the enamel, and the absence of pits and fissures, is a matter of the developmental side—nutrition and its effects on those organizers that control cellular activity during pregnancy, lactation and early childhood. The attack by caries is environmental. Both of these sides should be investigated piecemeal.

In the past, Pickerill sought an explanation on the basis of the physical environment of the tooth and the physical condition of the food.

The recently appointed Dean of the Dental School, Otago University, proposes to apply modern physico-chemical methods to a study of the environmental factors in the different types of caries.

Fluorine—Our interest in this element has stimulated several different lines of investigation.

(i) The Dominion Laboratory has published work to indicate that the fluorine content of New Zealand potable waters is generally very low.

(ii) The Soil Survey Department has examined soils, but finds that total fluorine in soil shows no deficiency. In the present state of doubt about methods, and in view of the uncertainty about availability of the element, they have meantime ceased to follow this line of enquiry, but expect to return to it if researches on the physiological side indicate that it is worthwhile.

(iii) The Nutrition Research Department has under review the fluorine content of teeth of human beings and the fluorine intake per day. When they have sufficient information on this point a paper will be presented by Marion Harrison.

(iv) The Department of Agriculture has been studying the fluorine content of the teeth of New Zealand sheep, for the following circumstance has occurred—that the teeth of sheep have shown a deterioration compared

with their capabilities in earlier times, with the result that in certain districts the ewe, formerly able to feed herself well enough to support her offspring during several successive reproductive seasons, is now able to support lactation for one year less. This means a very great economic loss.

If fluorine appears to be one of the factors at fault in New Zealand, researches on this line will be continued. It is not expected that it will by any means explain the whole of the dental caries problem.

Dissemination of scientific information

Though this properly belongs to morning subject (**e**), some of that section impinges on the subject of nutrition.

It would be appreciated, especially at this distance, if earlier information could reach us as to what is being done elsewhere. Those who have the opportunity to meet in groups for discussion of the same subjects can scarcely understand what it is like to work in isolation, waiting till reports are published, or still longer for abstracts to appear. Critical reviews would also be less disappointing than summaries of the bibliography.

As to the matter of spreading information to the public, we have played our part, through regular articles in the Press, lectures to nurses, etc.—and incidentally, these save the clerical work that is entailed in answering numerous individual inquiries. The Department of Health has pursued a vigorous campaign of education, through daily radio talks, posters in railway stations, advertisements in the Press, and through the issue of a booklet with a survey of the elementary facts of nutritional science and a translation of the League of Nations Technical Commission's standards into the form of menus and recipes. They have also had a mobile health exhibit, with cinema films and models, in which the school children who are taken to see it show considerable interest.

School lunches

Attempts to feed school children at lunch-time have been only on a small scale, and scattered. The basic drawback is the shortage of female labour. Many children come long distances.

Meals in industry

An adverse report was made by Davidson in the 1945 report of the Director-General of Health on the meal facilities in most of the factories.

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MEMORANDUM ON FOOD FROM COLONIAL FISHERIES

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FISH, which are believed to contain most of the essential proteins and most valuable mineral and protective elements besides, are especially important in the maritime Colonies either, as in the British West Indies, as an essential article of diet, or, especially in the urban areas, as an alternative source of first-class animal protein to meat from which it is often a welcome change.

Speaking generally the tropical marine fisheries are less productive than the temperate and high latitude fisheries, and certain areas (e.g. the Caribbean) rely to a considerable extent on imports of fishery products from these more highly productive areas (e.g. Newfoundland and Canada). However, marine productivity in the tropical Colonies is not everywhere as low as in the Carribbean, and there are unquestionably extensive fishery resources in the various Colonies which are at present under-exploited. This is due to a lack of precise knowledge of local abundance of fish, and of modern technology of fish-catching and preservation.

At present the Colonial fisheries are mostly peasant or native industries, using methods and craft developed by the indigenous peoples themselves. Although these methods, here and there, involve high standards of skill and daring, they are, for the most part, limited by the type of power available, namely oar and sail for propulsion, and man-power for manipulation; other limitations are inadequate methods of preservation of fish, and the strengths of local materials used in gear. The fisheries are largely exploited by small units either on the actual beaches (beach-haul seines), or close inshore (hand lines, etc.) within the limited range of small craft, and under the necessity of marketing the catch as soon as possible after it has been caught due to the high rate of deterioration at high temperatures.

The introduction of motor power both for propulsion and for handling gear would in most cases greatly increase the catching power of each craft, and suitable methods of preservation at sea and ashore would greatly widen their working range. These modern techniques, however, cannot always be immediately superimposed on old established fisheries, but call for a new approach in vessels, gear and methods.

It is first necessary in each Colony to catalogue the resources available, and this, in the long run, can only be done by direct methods of fishery exploration. Both the scope of the fishery resources, and the methods by which they may be made available, must be explored in the most practical manner by working over hitherto unexplored areas, and by trying out

every kind of fish-catching technique which can be brought to bear, using not only those methods which are so familiar to us in this country (e.g. the otter trawl, long lines, etc.), but also methods which have been successful under conditions more closely analogous to those in the Colonies (e.g. the purse-seine in Norway, Pacific Coast of North America, Japan, or multiple trolling in Brittany, Pacific Coasts, Japan).

The same principles apply also in the field of fish preservation—on ice, under cold storage, or by wet or dry salting. Methods require to be adapted on the spot to the often trying conditions of temperature, humidity, fuel and power supply, etc.

It is rarely possible for local private enterprise to undertake the difficult task of fishery exploration due to the unfamiliar techniques and the frequent disappointments ; it should therefore be a function of government, especially under the aegis of Development and Welfare, to institute fishery exploratory projects in order to work out and demonstrate to local fishermen and local capital the availability of local food fish and the techniques of catching and preservation which have been successfully adapted to local conditions.

In parallel with fishery exploration, a sound body of scientific knowledge must be built up around each fishery in order that the biology of each important food fish may be thoroughly understood and the fishery benefit accordingly, and that the fishery may later be exploited to the full without harmful over-exploitation and resultant decline in sustained yield.

Similarly the great fresh water lake fisheries of Central Africa must be explored and developed ; and fish farming, already so successful in Palestine and Malaya, is capable of development elsewhere especially in conjunction with rice padi cultivation and swamp reclamation.

In summary, therefore, it is necessary to estimate fairly closely the varying marine productivities in the waters of the various Colonial territories, and the abundance of the available food fish ; to devise suitable techniques of fish catching and preservation for their rational exploitation ; to develop fish farming in fresh and brackish waters under local conditions ; and at the same time to accumulate a body of fundamental scientific knowledge of the food fish and their environments.

For these ends the fullest support should be given to the establishment of regional Fishery Research Laboratories now envisaged by the Fishery Adviser to the Secretary of State for the Colonies, Mr C. F. Hickling.

THE PRESENT STATE OF THE SCIENCE OF NUTRITION (HUMAN) WITH PARTICULAR REFERENCE TO THE PROBLEMS OF AUSTRALIA

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BRIEF REVIEW OF NUTRITION PROBLEMS IN AUSTRALIA

Before 1936, although an appreciable number of isolated investigations has been made by workers in the universities, research institutions and public health departments, no organized investigation of the nutrition of the Australian people had been developed. A domestic food consumption survey and an extensive examination of the chemical composition of Australian foods was commenced in 1936. In 1938 organized laboratory research commenced at the Australian Institute of Anatomy, Canberra, whilst in 1944 and 1945 further food consumption surveys were undertaken.

The food consumption pattern of the Australian people is remarkably uniform, being based upon the traditional fare of England. Because of the extent of the wool industry, mutton has always been comparatively cheap and this has led to a universally high meat consumption, particularly in inland areas. In contrast to this, fresh fruit and green vegetables are generally scarce in inland areas, owing mainly to the great distances and the comparatively small populations there. Because of climatic factors and a limited water supply it is not possible to produce fruit and vegetables locally in many inland towns during the summer months. While canned vegetables and fruit juices would be a satisfactory substitute, the limited production of these in Australia before the present war did not ensure a regular and cheap supply of these articles to the inland towns.

The average *per capita* consumption of milk by the Australian population was considerably below that of the United States and the United Kingdom at the present time. Data from both food consumption surveys and source data indicate a low and perhaps unsatisfactory average *per capita* intake of calcium. This is a reflection of the comparatively low milk consumption.

Gross malnutrition resulting in the development of frank deficiency diseases, except in extremely rare circumstances, do not occur in Australia, although cases of minor departures from normal health due to inadequate diets do occur.

Australia produces its own requirements of the major food items and an exportable surplus of many of them. The main problem is the inadequate distribution of these foods, partly because of ignorance, partly because of poverty and partly because of an unsatisfactory distribution to many areas.

NUTRITION PROBLEMS IN AUSTRALIA'S DEPENDENCIES

Australia is responsible for the administration of certain islands in the Pacific—New Guinea and the Bismarck Archipelago—and is committed to the development of a satisfactory standard of life amongst the native population. The foremost requirement in this regard is a satisfactory standard of nutrition. The first step in this programme was the recent establishment by the Government of a satisfactory diet scale for native labourers. The next step is to endeavour to raise the level of food production in the native villages. This is a long-term programme.

CONTROL OF NUTRITION ACTIVITIES IN AUSTRALIA

In 1938 the National Health and Medical Research Council established a Nutrition Committee. The charter of the Committee was to foster (*a*) the general health of the rising generation ; (*b*) the correction of faulty dietary in a general sense, by the publication of sound propaganda and dietary advice from time to time ; (*c*) the investigation and rectification of specialized local defects, both physical and nutritional, by co-ordinated effort. The Committee is a technical one and its work during the last six years can be grouped under three main headings : (i) directing research ; (ii) advising upon nutrition education ; (iii) advising the Government concerning matters relating to food and nutrition, especially food rationing during the war years.

This Committee has no facilities for carrying out research itself, but undertakes the general supervision of research through its individual members.

FACILITIES FOR RESEARCH IN NUTRITION IN AUSTRALIA

1. Laboratory research

In general all universities have facilities for carrying out, to a limited extent, research in the biochemical problems of nutrition. The marked overcrowding of universities that will occur in the next few years will restrict the amount of work that can be done in this field.

The Commonwealth Government has established at the Australian Institute of Anatomy, Canberra, a central research institution for the investigation of nutrition problems in Australia and in its dependencies. Facilities for both laboratory and field research are available at the Australian Institute of Anatomy. During the last six years the staff has had considerable experience in two types of research—

(*a*) *Laboratory studies, including*

(i) Methods of determining nutrients in foodstuffs and biological fluids, including thiamine, riboflavin, nicotinic acid and ascorbic acid. Both chemical and microbiological methods are used.

(ii) Methods of assessing nutritional status—i.e. biochemical tests on blood, urine, etc., to determine if an individual is receiving sufficient or insufficient of a particular nutrient.

(iii) Analyses of various foods and food products.

(iv) Studies of the metabolism of vitamins of the vitamin B-group, including investigations of the vitamin content of human milk, metabolic experiments on rats and guinea-pigs and the nutritional requirements of micro-organisms.

(*b*) *Field studies, including food consumption surveys and nutrition surveys*

A number of these surveys have been carried out over the last few years and plans are developed for extending this work into other areas, including the Pacific Islands.

2. Apparatus available at the Institute of Anatomy

This includes fluorometers, colorimeters, absorptiometer and a well equipped animal house for carrying out metabolism experiments with animals.

TEACHING

Facilities exist in Australia for training workers in the field of nutrition. Adequate provision is made in four universities for training students in biochemistry and the principles of nutrition. However, there is no school of domestic science at any Australian university. This is a distinct handicap, particularly with regard to the training of teachers of domestic science in schools and technical colleges.

Until 1945 the principal defect was the absence of any training course for public health workers in nutrition. In that year the Commonwealth Government agreed to the establishment of a training school at the Institute of Anatomy, Canberra. A second course of instruction is being given this year. This course lasts an academic year and is divided into two parts. The first half, which occupies the first two university terms, is a theoretical course, whilst the second half lasting one term is devoted to field study. This takes the form of a food survey and is designed so that the students might become conversant with conditions in homes in various parts of Australia. The teaching in this course is at the post-graduate level and every endeavour is made to give each student training specialized to fit him or her to undertake the particular work which they desire to follow. The course is largely tailor-made for each student, although there is an appreciable amount of formal work required of the group as a whole. The class is limited to twelve students. A high percentage of the teaching is undertaken by the staff of the Institute, but some twenty per cent of lectures are given by visiting lecturers who are specialists in their own fields.

THE NEED FOR CO-OPERATIVE WORK WITH OTHER PARTS OF THE EMPIRE

The foregoing brief review indicates that Australia is very much alive to the need for the study of nutritional problems both in Australia and in the territories under her administration. Facilities exist for undertaking investigations in many branches of the science of nutrition and progress has already been made in the assembling of trained staff to do this.

As with many other branches of science, Australia's isolation places her workers at a disadvantage when it comes to consultation with investigators in similar fields overseas.

THE SELECTION AND IMPROVEMENT OF FOOD PLANTS

By A. GLENDON HILL
(Director, East African Agricultural Research Institute.)

THE selection and improvement of colonial food plants by plant-breeding should be an essential part of any general plan for bettering the nutrition of indigenous colonial peoples.

Unfortunately, this has not been generally recognized in the past. Where plant breeding has been provided for in our tropical dependencies, the work has usually been directed towards improving cash crops, such as cotton, probably because of the more immediate results which could be expected in the form of increased revenue. In those colonies where provision has been made for the scientific study of native food crops, the investigations have often been aimed at the direct attack on plant diseases and pests. There is little doubt in my mind that had our colonies spent more in the past on the indirect method of attacking plant pests and diseases through the medium of plant breeding, the health of the food crops and the standard of nutrition amongst our colonial peoples would be considerably higher than it is to-day. In support of this contention I would point out that the plant pathologist not infrequently has to become a plant breeder himself in order to solve his disease problems, the breeding of resistant strains often being more satisfactory than direct methods of attack, particularly when dealing with the crops of primitive farming communities.

One of the main reasons for the comparative neglect of plant breeding in the past has been the belief that the improvement of native farming methods should have priority over the improvement of crop varieties by plant breeding. There is much to be said for this point of view, but my own view is that neither method should be pursued alone : both must be carried out concurrently whenever possible. When setting out to improve the food crops of primitive indigenous peoples, plant breeding should be embarked upon as early as possible since it is the only scientific method whereby it is possible to bring about increased crop yield per acre without at the same time changing agricultural methods, or making greater demands on the strength, ability or skill of the farmer. If only because of this fact, it is a mistake to postpone plant breeding until the general standard of farming in the country has improved. I would make one proviso, however : it is essential to have a proper channel for the dissemination of the improved varieties. It is little use producing better crop varieties unless adequate machinery exists for distributing these varieties to native farmers and persuading them to make use of these by demonstrating their advantages. In primitive communities government agencies must undertake this function of seed distribution, otherwise the work of the plant breeder is largely wasted.

Yet another reason, apart from the war, for the comparatively backward state of native food crop improvement in our colonies, has been the lack of trained plant breeders. All too often the work of food-crop improvement has had to be left to already over-burdened agricultural officers who, in any case, are usually unable to carry out such work properly owing to the large amount of their time spent in travelling. In East Africa an agricultural officer is not infrequently absent from his headquarters for half the month, with the result that he cannot give the necessary time to plant breeding—which is an exacting and whole-time occupation when properly carried out.

It is not generally realized what a vast and promising field awaits the scientific plant breeder in many of our colonies, particularly in Africa. The food crops of the ancient civilizations of Europe and Asia have undergone improvement by highly successful empirical methods extending over centuries, but in the case of the food plants of tropical Africa, a region which only recently emerged from a state of constant inter-tribal wars and migrations, the process of crop improvement is still in the primitive stage. For this reason it should be comparatively easy to achieve a very substantial increase in food crop yields in a relatively short time by simple selection methods alone, without resorting to long-term breeding based on genetics. In Europe and North America private individuals and seed merchants were the first to undertake the sorting-out and improvement of crop varieties, using farmers' mixtures as their raw material, and very great improvements were made in this way through selection alone, even before anything was known about the laws of inheritance. However, we cannot expect private individuals or firms to perform this function to-day in our tropical dependencies where there is no market for seed among native farmers and for this reason the work must be undertaken by government departments.

Notable progress has already been made by the agricultural departments in some of our colonies with the improvement of certain cash crops, such as sugar-cane, cotton, coffee and wheat ; but this is not enough. In future we must give equal consideration to the improvement of the common native food crops, and make provision for the setting-up of plant breeding stations solely for these crops. The shortage of plant breeders rather than shortage of funds is likely to prove the main hindrance to progress.

From what I have said it might be supposed that I considered the task of the plant breeder in the tropics was a comparatively easy one. This is not so. Apart from the difficulty of working in extreme heat, often with unskilled and illiterate helpers, the plant breeder in the tropics finds himself up against all sorts of difficult problems, some of them the result of the environment, others man-made. Two problems in my own experience will illustrate my point. In North Nigeria, where sorghum millets are the major grain crop, it was found that selected strains which gave increased yields in their own district appeared to be incapable of competing with unimproved local varieties when grown elsewhere, even if only a few miles away : thus indicating a degree of local adaptability amongst sorghum varieties which completely upsets the plant breeders calculations.

The second example comes from East Africa, where in the case of cassava selected for resistance to virus disease it has been found that clones

which are resistant in North-East Tanganyika may prove highly susceptible when grown elsewhere in East Africa, thus making it necessary to carry out selection for virus resistance in each of the main cassava growing areas.

When setting out to improve the nutrition of a primitive agricultural community, the initial inquiries should, I think, be drawn up on comparatively simple lines, and should not be allowed to become too diffuse. In the first instance inquiries should, I consider, be confined to two vital questions : i.e. what are the main deficiencies in the local diet and how can these be best overcome.

On the answer to these two questions will depend the nature of the plant breeding programme to be undertaken in each territory. In drawing up a plant breeding programme we have to decide at an early stage whether to aim at improving quality as well as quantity. Personally, I am of the opinion that when dealing with the native food crops of a primitive community, the plant breeder should first aim at securing the largest and healthiest crops per acre and should not concern himself with attempting to alter their composition, except in regard to carotine content in, say, maize and sweet potatoes where, other things being equal, yellow varieties are to be preferred. Assuming that eating and keeping qualities are satisfactory, the best crop varieties for the native farmer producing his own food are those which give the greatest yield per acre. The main consideration, I believe, is food value per acre and not food value per ton of produce. Where the local diet is scanty and ill-balanced, as it is in many parts of the tropics, no amount of improvement in quality is going to convert such a diet into a full and well-balanced one. It will be time enough therefore to attempt improvements in the composition of food crops when the problem of supplying the necessary bulk and variation in diet has been achieved.

The war having ended, plans are now being drawn up for the reorganization of scientific research in our tropical dependencies, and it is therefore appropriate to consider what form our future plant breeding programmes should take.

Some of our dependencies contain a vast number of crop varieties, most of them mixed, about which very little is known. Therefore one of the first items in a plant breeding programme should be a survey of the native crop varieties in each territory. These should be collected, sorted out, and tested under a wide range of conditions—the best being selected for further trials. When the possibilities of improving these crops by ordinary selection methods have been exhausted, then crossing should be exploited. Apart from breeding work the programme should make provision for the importation, through quarantine, of promising new varieties, as well as wild forms for use as breeding material.

In any plant breeding programme designed for our African colonies special attention should be directed to the production of short-term millets and maize suitable for the semi-arid zones where little can be grown at present. Great areas in the cold northern regions of Canada, Russia and Sweden have been converted into productive farm-lands by breeding new crop varieties to suit them, and one is tempted to hope that the plant breeder, with the help of the plant physiologist, may also be able to turn some of the great semi-arid areas of our tropical colonies into productive

farm-lands by breeding suitable drought-resistant crops, thus relieving the pressure on the land in the areas of higher rainfall.

Apart from breeding for drought-resistance, there is a need for cereal varieties which are resistant to striga or witch-weed—a major pest in some areas.

The impact of our civilization on the tropics has had some unexpected results : one example being the great increase in bird-damage to grain crops now that so many native children go to school and so are no longer available for bird-scaring. Because of this new situation there is an urgent need for the plant breeder to produce bird-proof varieties of millet and other grain crops.

Apart from the need for improving the staple grain crops, it is highly desirable that large-scale breeding work should be carried out with the pulse crops, including the soya bean, a plant which although not of tropical origin, has proved itself adaptable to a wide range of conditions. It is not to be expected that ready-made soya varieties suitable for our tropical dependencies will be found, but it should be possible to breed varieties suited to the conditions found at medium and high elevations in the tropics. Some agriculturists argue that it is pointless to worry with the soya bean in the tropics when one has an admirable crop like the ground-nut already established there. There is a lot to be said for this view, and there is always the assumption that a long established, or indigenous, plant will respond better to development than a new introduction : but the peculiar merits of the soya bean and the enormous range of its food products—which include a very useful milk substitute—make it desirable that its possibilities should be fully investigated in our tropical dependencies.

Another plant awaiting the attention of the plant-breeder in the tropics is the so-called Irish potato, a crop which until the sudden appearance of Late Blight in Kenya, some four or five years ago, was well on its way to becoming a major food crop amongst the natives living in the East African highlands. The new knowledge of potato breeding in Britain, following on the discovery of new breeding material in South America, holds out the hope that blight-proof potato varieties can be had to replace the susceptible varieties of the past, the loss of which was a serious blow to the native farmer.

While on the subject of root crops, I should like to say a word in defence of cassava which was scornfully referred to at the Hot Springs Conference as a lazy man's crop. While admitting its imperfections as a staple food, the value of cassava as the main source of starch for many thousands of Africans cannot be doubted. Apart from its hardiness and the ease with which it can be grown, cassava has the added advantage of being notably resistant to drought and locusts, while the fact that its roots can be left in the ground unharvested for long periods makes it a valuable food reserve and a protection against famine.

All nutrition workers would, I think, agree that there is need for introducing cultivated green vegetables into the native diet in most of our colonies. Almost all African tribes collect and use wild plants as vegetables, but in tropical Africa as a whole one does not find any cultivated vegetables to correspond with the cruciferous vegetables which form so important a part of the supplementary diet of European and Asiatic peoples. Africans,

it is true, are beginning to appreciate some of our European vegetables—an appreciation which sometimes manifests itself in the form of extensive praedial larceny. But our so-called European vegetables usually thrive only in the cooler parts of the tropics, and there is a need for carrying out breeding and selection amongst the better known wild spinach plants of the tropical lowlands, such as the edible *Amaranthus* and *Rumex* species.

In conclusion, we are faced to-day with the gigantic problem of how to provide a better standard of nutrition for the vast and varied population of our Colonial dependencies where, in some regions, we are up against the spectre of an increasing population accompanied by a decreasing soil fertility brought about by soil erosion and other causes. In order to help solve this frightening problem, we should put the improvement of food plants by plant breeding in the forefront of our policy, and set up special plant breeding stations where necessary for native food crops. The plant breeder, in collaboration with the nutrition worker, can play a major part in helping to solve the nutrition problem by breeding more productive food plants for direct or indirect consumption by man. At present the science of plant breeding is not being made full use of in our colonies, nor can it be made full use of until the number of plant breeders trained in Great Britain and the Commonwealth is increased very considerably.

NUTRITION IN CEYLON

By Professor W. A. E. KARUNARATNE
(Professor of Pathology, University of Ceylon)

NUTRITION is a young science and most of our knowledge of this subject is quite recent. The serious effects of malnutrition on health manifested themselves in a very marked manner during the world economic depression (1929–1933).

In Ceylon, little or no attention was paid to this subject till the attention of the Government was directed to a peculiar skin eruption amongst a large number of prisoners in the Colombo jail. Dr Lucius Nicholls, the then Director of the Bacteriological Institute, was called upon to investigate the condition. He thought that it was a manifestation of nutritional deficiency and found that it could be cured with cod-liver oil. Before Dr Nicholls, another worker in the same field, Dr D. C. de Fonseka, had noted the fact of this eruption and that the sufferers reacted very favourably to cod-liver oil. Later investigations showed that the condition was quite common in other prisoners, among poor hospital patients, children in orphanages and schools in the rural areas. The skin affection was called Phrynoderma. It may be mentioned that Pillat, and Frazier and Hu reported cases of this type prior to Dr Nicholls, and the two latter observers definitely attributed the condition to vitamin A deficiency. It was soon recognized that other conditions caused by nutritional defects such as sore mouth, angular stomatitis, keratomalacia, xerophthalmia, Bitot's spots, etc., were widely prevalent in Ceylon. This knowledge of the wide prevalence of nutritional deficiencies led to more elaborate investigation, and in 1936 a nutritional survey of the poorer classes in Ceylon was undertaken by Dr Nicholls. A study was made of the heights and weights of children taken from the various strata of society. The details will be given elsewhere, but there was definite evidence that although the Cingalese were composed of several races, the differences in weight and height were not dependent on race but on the economic and social status of the children. Nicholls also discussed the effect of malnutrition on the morbidity and mortality rates. Two sessional papers on nutrition in Ceylon were thereupon published, one by the Director of Medical and Sanitary Services and the other by Dr Nicholls. The latter paper consisted of biological assays and chemical analyses of Ceylon foodstuffs and a survey of Ceylon diets. This investigation marked a definite advance in nutrition, and medical practitioners as well as laymen became aware on a wider scale of the chemical constituents and the nutritional value of the common foodstuffs available in Ceylon. In the following year a Nutritional Branch of the Department of Medical and Sanitary Services was established. Much work has already been done, as will be seen in the pages that follow, but much still remains to be done.

The state of nutrition of the children of the upper classes, as presented

by those attending the larger schools such as the Royal College, was compared with that of the middle-class school children and also with that of the children attending the vernacular schools whose parents are of the poorer classes. It was found that the children of the upper classes were of larger build than those of the labouring classes. The former were taller and heavier than the latter. This marked disparity between the nutritional state of the children of the poor class and that of the children of the rich was solely dependent on the differences between the respective qualities of the diets consumed by them. It was found that the diets of the latter were superior in quality, especially in respect of fresh vegetables and comestibles of animal origin. The relationship of height and weight to diets was further emphasized by comparing the heights and weights of Cingalese children with those of two African tribes—the meat-eating and the milk-drinking Masai tribe and the more or less vegetarian Kikuyu tribe. The upper class Cingalese children showed a growth similar to that of the former while the children of the poor class showed approximately the same growth as the latter.

It was also found that the weight at birth of the children of the lower class was on an average about a pound less than that of children of the middle class. The determining factor of the difference in weight was the economic condition of each class.

Children drawn from the poorer classes were undernourished and showed nutritional defects such as phrynoderma (29·2 per cent), sore mouth (7·7 per cent), Bitot's spots, keratomalacia and various affections of the teeth, viz. hypoplasia, caries and mal-occlusion. Blindness is common in Ceylon. A study of 147 cases in the blind school showed that more than 60 per cent were blind as the result of keratomalacia due to severe deficiency of vitamin A.

Ceylon has a high infant mortality rate—nearly three times the rate for England and Wales. It has been shown that more than a third of infantile deaths were caused by malnutrition, prematurity and debility. A good number of the infants were born underweight and immature. A state of malnutrition in the mother was mainly responsible for the immaturity. The maternal mortality rate is also very high—about four times the rate for England and Wales. Malnutrition of the expectant mother was a predominant cause.

Although malnutrition plays an important part in the high infantile mortality rates prevalent in Ceylon, infections and infestations such as malaria and hookworm also contribute to these high rates. The lowering of the general resistance from faulty nutrition tends to increase the severity of such diseases as malaria and hookworm, conducing to a prolonged convalescence and a high mortality rate. During the malaria epidemic of 1934–1935, undernourishment and semi-starvation were as responsible as the disease for the high mortality. In a sessional paper on this epidemic the relationship of malaria to malnutrition is summed up as follows : ' Even if the masses had been well-fed and prosperous, there would have been an epidemic of malaria but the vicious circle of malaria and destitution acting and reacting on one another would not have been established and the mortality rate would have been lower, convalescence would have been shorter and probably the infectivity and

relapse rates would have been less.' It should also be realized that apart from directly causing disease, malnutrition produces effects on physical and mental vigour and well-being. It leads to apathy, want of initiative and incapacity for hard work, poor output of labour and consequent economic loss. A vicious circle is thus created.

In a recent investigation (unpublished) carried out by Professor Fernando in a large children's hospital in Colombo, it was found that 72·9 per cent of the children had clinical evidence of malnutrition. The clinical conditions noticed were anaemia, 89 per cent ; nutritional oedema, 16·1 per cent ; vitamin A deficiency, e.g., nightblindness, phrynoderma, xerophthalmia, Bitot's spots, keratomalacia, etc., in 19·5 per cent. ; vitamin B deficiency, 25·1 per cent ; rickets, 2·9 per cent ; scurvy, ·24 per cent ; dental caries, 30 per cent.

Rural dietary surveys conducted by Nicholls and Nimalasuriya (1941) revealed a serious state of affairs. They found that a high percentage of the people consumed diets which were deficient not only in caloric value but also in important constituents. Nearly two-fifths of the rural population did not obtain a sufficient quantity of food. Many of the diets were deficient in protective foods, the notable deficiencies being protein of high biological value, calcium and vitamins A and B. Fifty-five per cent of the families received less than 60 g. of proteins and 56 per cent less than 0·4 g. of calcium per adult unit per day.

It follows from these investigations that the present state of nutrition in Ceylon is by no means satisfactory. A large proportion of the popula tion consumes insufficient or defective diets which lead to various forms of ill-health or stunted growth in children. They also lower resistance to infection and increase the severity of infections such as malaria, ankylostomiasis, dysentery and tuberculosis.

A satisfactory state of nutrition could only be realized by the consumption of the right type of diet, and this is dependent in its turn on our ability to produce a sufficient quantity of the proper food. For this purpose a proportionate extent of land should be cultivated.

Ceylon is an agricultural country but it is far from self-supporting in essential foodstuffs. It has a population of six and a half millions, but less than a third of the total cultivable area is under food crops. She produces only about a third of her food requirements. She is forced to import yearly from India and Burma foodstuffs to the value of over one hundred million rupees. A higher standard of nutrition, therefore, demands greater development in agriculture, improvement in animal husbandry and fisheries.

A step in the right direction was taken recently when, on account of the critical food situation caused by the world war, people were compelled by law to produce food crops on their lands. Vast tracts of jungle were opened up by the Government and given to the peasants for cultivation. Irrigational projects are also being put into operation. The hydro-electric scheme, envisaged so many years ago and which promises at last to be realized, will be a great boon to industry. All these augur well for the future. There is also the economic factor to be considered. Rice is the staple article of diet of a large number of the people. Very little meat, eggs and milk are taken ; the consumption of pulses and leafy vegetables

is poor. The average cost of such a diet in pre-war times was between 10 and 15 cents. Two or three times this amount would be necessary to improve it to the standard of an optimum diet. An appreciable increase in the income is therefore essential.

The State has been alive to the unsatisfactory nutritional conditions of the people. It has also realized that this has been partly caused by ignorance of the peasant regarding nutritional matters and has attempted to combat the present condition by the creation of a new department dealing solely with nutritional problems. I have already mentioned some of the investigations carried out by this department. It has also, with the help of the London School of Tropical Medicine and Hygiene, made chemical analyses and biological assays of the various foods. This knowledge is now available to both the doctor and the layman. The department has also been responsible for propaganda which has spread to the remotest villages. Health news and articles on nutrition appear frequently in the public press. Periodical lectures by officials in the department are given in schools and nutrition is made a compulsory subject for school children.

The importance of nutrition is also emphasized in lectures and demonstrations given by departmental officers to school teachers, divisional revenue officers, sanitary inspectors, public health nurses, medical students and even doctors who are engaged in duties which bring them into contact with the rural population. The dissemination of knowledge regarding diets is also effected by exhibitions, radio talks and printed leaflets. Nutritional defects are taken note of in ante-natal, child-welfare and school clinics and corrected early. A free midday meal is supplied by the Government to all school children of the lower class.

A plan for the future should take into consideration several important problems, viz., the extent of cultivable land, the further development of irrigation, the prevalence of malaria as also the rapidly increasing population. All these are intimately bound up with food production.

Ceylon is divisible into two zones, the dry and the wet, according to the rainfall. The wet zone is fully absorbed by various industries, viz., rubber, tea and coco-nut. The success of food production will therefore depend on the cultivation of the dry zone which occupies about two-thirds of the island and consists mainly of jungle. At present it is very thinly populated. In ancient times the dry zone was thickly populated and cultivated with food crops. It was irrigated by a system of tanks. Malaria appears to have been responsible for the depopulation. Paddy cultivation was abandoned and the tanks fell into disuse.

The increase of food production would therefore depend on a plan which envisages the irrigation of the dry zone. Some of the smaller tanks have already been restored. As this zone is sparsely populated a system of colonization should be introduced. The greatest obstacle to colonization and recultivation of these once fertile areas is the wide prevalence of malaria. It should be remembered that malarious areas such as Palestine and the Roman Campagne have been successfully colonized.

The fact of a systematically increasing population should also be taken into account. The population of Ceylon, which was a little over two millions in 1870, has risen to over six and a half millions.

If agriculture is carried on in the present haphazard hand-to-mouth basis the increase in population will soon exceed the available food supply. The solution of the problem lies in the utilization of modern scientific facilities and industrial advancements for agricultural development ; the use of pure line seed paddy and proper soil cultivation. In this way, lands under cultivation could be made to produce an enhanced yield. The yield of paddy at present is very low—an average of ten to twelve-fold, but other countries using modern methods have secured yields averaging well over forty-five fold.

Agriculture and farming must be developed scientifically. Adequate nutrition is, in the last analysis, a problem of education and government. As McLester says : ' In the future it promises to those races which will take advantage of the newer knowledge of nutrition a larger stature, greater vigour, increased longevity and a higher level of cultural attainment.'

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THE PRESENT STATE OF NUTRITIONAL SCIENCE IN CANADA, INCLUDING REFERENCE TO THE NUTRITIONAL STATUS OF INDIGENOUS PEOPLES

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ANY deviation of the food intake from the level needed by an individual for optimal nourishment of the body tissues, having regard to actual utilization, may result in malnutrition. In practice almost all harmful deviations are *below* the needed level, although an excess of calories, which may result in obesity, is often considered malnutrition; it may be accompanied by an inadequate intake of other nutrients.

In essence, therefore, the nutrition problem is a medical one consisting in the diagnosis of those individuals who could benefit by improved dietaries. The solution of the problem is providing these people with the information about, and the means of obtaining, the necessary diets. In fact, however, there is still no sure way of diagnosing much of the malnutrition that may exist, and the solution of the problem involves a vast number of subjects ranging from the availability of refrigeration to the statistical quantity of food used within the country, and from the cost of transportation to the need for skilfully apportioning the family income among food, shelter and other essentials.

Under these circumstances it is understandable that the nutrition problem is still one of research on the one hand and of rather general public health measures aimed at prevention, on the other. In most countries the subject is one of gross deficiency diseases from the medical standpoint, and of gross statistics of food consumption, while in only a few countries, including Canada, is it a question of the more refined medical considerations, and of the precise quality, rather than the quantity of foods available.

Both the presentation of the food statistics and studies of food habits, food consumption, dietary and nutritional status have received considerable attention in Canada in recent years. The evidence for malnutrition in Canada up to 1944 was reviewed by Pett (1944), and a study to be available in May, 1946, from the Department of National Health and Welfare entitled '*A Report on Nutrition and the Production and Distribution of Food*' gives a rather complete indication of the statistical, agricultural, economic and other factors, together with a full bibliography of pertinent material up to July, 1945. Therefore, references will be included here only to such work as has appeared in accessible form since that date.

No comprehensive picture of the nutritional status of the Canadian people can yet be given. A few persons die every year from diagnosed

dietary deficiency diseases such as rickets and scurvy ; probably many cases exist for one that dies. The food statistics show that the production of food in Canada is more than enough to satisfy the needs of the people, and the amounts actually consumed provide a high level of nutrition, though perhaps qualitatively not entirely adequate. Feeding demonstrations on three quite different groups, school children, factory workers and pregnant women have shown improvement in health as a result of extra foods provided above the diet normally consumed. Dietary and food consumption surveys made in Canada have indicated the presence of some under feeding in certain groups. Medical studies have shown a small incidence of signs associated with malnutrition. Such surveys have been few in number, widely scattered, restricted to certain selected groups where malnutrition might not have been expected, and have usually been limited in their techniques. Much more work of a systematic nature will be necessary on food composition and processing, on dietary requirements, on nutritional status in a broad field, before a comprehensive picture of the actual state of nutrition in Canada can be clearly described, but it is clear that the level is a fairly high one. The present state of affairs and trends for the future will be considered under three headings : (1) organization for work in nutrition in Canada, (2) problems in nutrition now receiving attention, (3) nutritional status of indigenous peoples.

1. ORGANIZATION FOR WORK IN NUTRITION IN CANADA

Advisory groups in nutrition

Canadian council on nutrition—The chief pre-war advisory group in nutrition was called the Canadian Council on Nutrition, a group of thirty-five people representing very diverse interests set up in accordance with the recommendations of the League of Nations by the Minister of Pensions and National Health. This Council held an annual meeting but functioned chiefly through its committees. The Surveys Committee sponsored dietary surveys by the weighing method in 1939–1940 in four cities of Canada. The Food Composition Committee advised the Department on grants of money to universities for food analyses, and for work on methods of assay which have yielded much valuable information. The School Lunch Committee drew up plans for a comprehensive scheme of federal aid in school lunches, which has unfortunately not yet been implemented. Advice has also been given in connexion with the administration of the Food and Drugs Act, and on such diverse subjects as lifeboat emergency rations, Eskimo diets, and a propaganda programme. This Council has recently been reconstituted under the Minister of National Health and Welfare with representation from a scientific group used by the Food and Drugs administration, from a dominion-provincial nutritionists committee, and from others concerned with nutritional education in a broad sense.

Other advisory groups—In spite of the seeming comprehensive nature of the Nutrition Council many other advisory groups function in Canada without any formal co-ordination. During the war the Army and Air Force had a separate advisory committee, and then each applied the advice

differently. The Navy had another group of consultants and worked independently. Other federal departments which sought separate advice on nutrition included the Indian Affairs Branch and the Foods and Ration Administrations. The nutrition work of the Canadian Red Cross Society had its own advisory committee, and was further complicated by a separate advisory group in each of the nine provincial divisions. Other voluntary and professional organizations which carried out nutrition work of importance and had separate advisory groups included the Canadian Medical Association, the Health League of Canada and the Life Insurance Officers' Association.

Organization for nutritional research

Most of the nutritional research in Canada has been done in university departments of biochemistry or physiology, and to a limited extent in departments of medicine or in hospitals. This research has been assisted in many instances by grants from the National Research Council. It naturally tends to be unco-ordinated, and depends on the interests of some particular professor, and on his ability to get financial support for the project. Much valuable information has been obtained in the National Research Laboratories, usually devoted to some practical industrial application. During the war notable contributions were made to such problems as meat storage. Some similar work is done by commercial interests, but the proximity of the United States of America, and the contact between Canadian and American food manufacturers has tended to minimize the amount of research done in Canada by this source. Other governmental sources of nutritional research include the Fisheries Research Board, the Dominion Department of Agriculture, and the Department of National Health and Welfare.

The Fisheries Research Board maintains several laboratories and has made many notable contributions concerning the composition and processing of fish and fish products from both the Atlantic and Pacific Oceans. The reports of the Board may be obtained from the Department of Fisheries, Ottawa.

The Dominion Department of Agriculture maintains various laboratories, especially in its experimental farm system, for the analysis of products and other fundamental investigations. During the war it did a notable service in connexion with dehydration methods and control.

The Department of National Health and Welfare has an elaborate system of chemical laboratories for control work under the Food and Drugs Act, in which new methods are frequently evolved, especially in the Ottawa laboratory. For biological work, including vitamin control and research, the Laboratory of Hygiene at Ottawa has developed extensively in both standardization of methods and other types of research. The Nutrition Division on the other hand confines research to assessment of nutritional status by dietary, clinical and biochemical methods, including maintenance of a clinical nutritional laboratory, and making surveys. It will be noted that the research work of this Department, and the advisory groups used are concerned with the Administration of Acts, either specifically like the Food and Drugs Act, or generally as in the maintenance of the health of Canadians which involves a study of their health. This type of research

or advice has not normally been obtainable from other sources such as the National Research Council or from universities and must therefore be developed departmentally.

Organization for nutritional information

Formal education in Canada is obtained through the nine different school systems (one for each province) in which there is little similarity in the methods of handling the subject of nutrition. In the universities only the School of Hygiene at Toronto has a department of nutrition, and elsewhere the subject is included in several different courses. Considerable work has been done in Canada by voluntary agencies in providing the public with information about nutrition and what foods to eat for health. The work of the voluntary agency is best devoted to filling in emergency gaps or jobs not suitable for government agencies, and to demonstrating needs for educational or other work for government agencies to take up. Assistance can also be given by studying methods that might be used. This is the pattern of organization that appears to be developing in nutritional education in Canada, since municipal and provincial departments of government (especially health departments) are appointing nutritionists as part of health education and as consultants to nurses and others. Voluntary agencies who have pioneered this work are going on to show how these government agencies can extend their work. Material assistance is rendered by the dominion nutritionists. A great problem in all this work is the lack of personnel trained for public health work in nutrition. Nowhere in Canada is there a course, even undergraduate, which has the necessary scope for this type of work.

2. PROBLEMS IN NUTRITION NOW RECEIVING ATTENTION

Only a general outline can be given of the type of work going on in nutrition in Canada and how it is being done, since there is no co-ordinating mechanism, nor even a Nutrition Society which could receive or discuss different phases of the work. This outline parallels the information given on organization, in section 1, above, but is classified differently.

University research

Research on nutrition in Canadian universities has included such diverse fields as development of a good biological method of assaying vitamin C or ascorbic acid, and investigations of thiamine requirement, analyses of foods, methods of conducting surveys, rehabilitation of hospital patients, and many other topics are all receiving attention.

Food and drugs standards on a nutritional basis

There is a trend toward the establishment of food standards to encourage the highest possible nutritional value naturally available, and deprecating the use of synthetic vitamins in foods. This trend is based on the obvious need for more knowledge of the subject both as to the need for such vitamins in the national diet, since excesses would be wasteful, and to the possible harm from such additions grossly unbalancing the intake of correlated

vitamins. Development of more accurate methods of analysis to assist in control work is the chief research in this field.

Food composition and processing

Several universities and different departments of government carry out thousands of food analyses yearly, but the results are frequently difficult to compare owing to differences in methods of analysis. Collaborative assays during recent years on a standard sample have shown wide variations in results from different places, even when allegedly using the same method. These results demand much greater attention in the future. Very little information is available in Canada on regional differences in food analyses, and this field promises to be important because it is clear, for example, that the areas producing most of the canned fruits and vegetables in Canada are the chief goitre areas. Some attention has been given to analysing cooked foods, yet much work remains to be done on a strict comparative basis with the raw food used, especially in regard to moisture content. A table of food composition for Canada is about to be issued by the Department of National Health and Welfare, Ottawa.

Statistical studies

Two types of statistical studies are undergoing active development in Canada. Mortality statistics such as those given in table I are being constantly improved, and efforts are being made to secure morbidity records. These are the bed-rock of medical science and the evaluation of nutritional status. (See table I.)

The other type of statistical material is that of gross food supplies adjusted for exports, seed, feed, waste and stocks, so as to arrive at a figure sometimes called 'domestic disappearance,' and supposed to correspond closely to the food of the country at a retail store level. Improved methods of calculating and adjusting such figures have been evolved during the war by participation with the United Kingdom and the United States in a Combined Food Board Committee. A recent publication of the Department of National Health and Welfare called *Canadian Food and Nutrition Statistics, 1935 to 1945*, brings these figures up to date. (See table II.)

Since such figures are usually given in quantities per person per year or per day they carry a strong but false suggestion of having been consumed by each person, when in fact they are national averages, which still need to be correlated with direct surveys on a sampling basis. Such surveys are being studied in Canada. From both types of statistics it is clear that Canada is among the best fed nations in the world, having both a low death rate from dietary deficiency diseases, and a generous amount of food to eat. This only serves to emphasize the type of nutrition problem found here.

Demonstration feeding projects

Demonstrations have been and are being made in Canada of the advantages in supplementing the foods ordinarily being consumed by certain groups with other foods. A demonstration sponsored by the Kiwanis Club of Toronto on school children was one of the first, and is now to be followed by a more extensive one on the benefits observable

from a school lunch. The observations of Ebbs and others on giving a few extra foods to pregnant women with resultant benefits both to mother and child are now widely known. It is important to note that these are direct demonstrations of the benefits derived from better feeding, and do not depend on the more theoretical questions such as dietary requirements or food composition. More such demonstrations should prove most valuable for advancing knowledge along with practice in nutrition.

Studies on nutritional status

Some universities, particularly from 1939 to 1944, did pioneer work especially in conducting dietary surveys, but the medical schools and medical profession generally have not taken an active part in the broader question of nutritional status. Furthermore, there has been an unfortunate tendency to consider vitamin status as synonymous with nutritional status. Some clarification has been achieved by the Surveys Committee of the Canadian Council on Nutrition, and by the efforts of the Nutrition Division of the Department of National Health and Welfare, as well as by the valuable work done in the various services during the war.

As pointed out in the introduction, the fundamental nutritional problem is a clear definition of the extent of malnutrition among the people and of the factors producing it. With this information available, even in broad outline, then a solution of the problem can be evolved along the necessarily diverse lines such as general economic and social improvement, food composition and processing, and public information. In this way may be reached a satisfactory approach to the goal of making it easy for everyone to be well nourished.

The necessary definition of the problem is therefore not exclusively a medical one, since it also concerns food habits and many other factors. These factors have been taken into account in developing the present method of nutrition surveys by the Department of National Health and Welfare, which include (i) a dietary study to indicate the food habits on which improvement must be based, (ii) a clinical study of brief and specialized nature, (iii) a biochemical study on finger-prick blood, including haemoglobin levels and microanalyses, and finally (iv) some sociological inquiries to aid in evolving the solution of what is found. This procedure is being applied first to school children in representative areas throughout Canada and will probably be completed in 1947, when more detailed work will begin. Methods will be adapted to newer research findings as they appear, and it is also believed that an indication will be secured of the most urgent needs for research from the viewpoint of public health. Financial help in this research will then be provided. Two specially trained nutrition survey teams are available, and considerable help is secured locally. Close contact has been maintained with similar developments in the United States and in Great Britain. Further contacts with other parts of the British Empire might be of distinct advantage.

Public information on nutrition

The great interest in nutrition aroused during the war appears likely to be followed by serious consideration of the effectiveness in Canada of

different approaches to the public. The aid of food processors appears important in the future, as the definition of the problem becomes more precise, in helping people to be well nourished, and making it difficult for people not to be well nourished. The schools will receive more direct attention. There are signs in Canada of moving away from the early types of adult education into a more solid yet extensive type of nutrition education, coupled with nutritionally improved foods. The effectiveness of different techniques is being studied and the co-ordination of activities by various groups is being attempted by the Department of National Health and Welfare.

Catering

Catering in general, but especially quantity cookery in hospitals, orphanages, industrial cafeterias and camps, received considerable attention during the war, and this interest in doing a good job, nutritionally, promises to continue. Numerous studies along these lines are going on in Canada, including one for small municipal hospitals (30 to 100 beds) not supporting a dietitian but which might benefit from a travelling dietitian visiting each of several on a circuit. This may be very important in the development of health services in Canada, which is about half rural.

3. INDIGENOUS PEOPLES OF CANADA—NUTRITIONAL STATUS

The indigenous population of Canada is now represented by about 126,000 Red Indians and about 11,000 Eskimos, or a little over 1 per cent of the total population. In spite of a high mortality rate the number appears to be slowly increasing.

As regards the Indians in Canada, about half are divided into three groups which are scarcely distinguishable in standard of living from lower white groups in the same areas. These three groups include the agricultural groups of Ontario and Quebec, the buffalo hunters of the plains who now raise horses and cattle, and the coastal Indians who fish.

The other half of the Indians, or about 60,000, and the 11,000 Eskimos are scattered throughout the north country in relatively primitive conditions. They are the hunters and trappers, and certain general statements may be made about them. So long as these natives use their original food habits, living off the land, they appear to have excellent health and stamina, but the more they depend on trading posts for food, the less satisfactory is their health. They are particularly susceptible to tuberculosis, with a death rate in 1942 of 732 per 100,000, compared with 51·4 for the rest of Canada. Infant mortality in 1942 was about 400 per 1000 live births in one study, compared with 52 for the rest of Canada.

The Department of Mines and Resources, under which both Indians and Eskimos are administered, has long been aware of these problems, and has striven to alleviate them. Contact with this group is difficult and sporadic, and a lack of detailed information has been a handicap. Several investigations have been made, but every one of them has covered only very limited areas or groups often just those near a post, and thus

not representative of the group in any way. Furthermore, the investigators have pursued their own particular interests, thus giving rise to distorted and even contradictory reports, such as the debate on whether Eskimos have no dental caries, and how the Indians and Eskimos get enough vitamin C to avoid scurvy, which is very rare. The best and most recent study on bush Indians has been reported in 1946 by Moore *et al.*

Just as the solution of any malnutrition among the general population of Canada may depend as much on other factors than food and resources, so also the solution of malnutrition among Indians and Eskimos may rest on such considerations as the source of fuel, or the improvement of native food supplies or the development of their own business leadership, rather than the administration of a few vitamins.

References

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Pett, L. B. 1944. Malnutrition in Canada. *Canad. med. Ass. J.*, **50,** 9.

Report on Nutrition and the Production and Distribution of Food. 1946. *Prepared under direction of an Interdepartmental Committee and published by the Department of National Health and Welfare, Ottawa, Canada.*

TABLE I

Number of deaths ascribed directly to nutritional deficiency diseases in Canada, excluding remote areas—1929 to 1944

	scurvy	beriberi	pellagra (non-alcoholic)	rickets	osteomalacia
1929	5	2	8	203	not available
1930	7	0	3	200	not available
1931	5	1	8	102	4
1932	10	1	6	95	1
1933	2	1	8	66	5
1934	6	0	1	72	4
1935	10	3	3	51	5
1936	12	1	2	68	5
1937	7	1	2	54	5
1938	11	1	2	61	4
1939	11	2	6	49	4
1940	6	1	3	66	5
1941	3	4	4	48	5
1942	2	3	2	45	1
1943	6	1	4	37	not available
1944	4	1	3	34	not available

TABLE II

Estimated average supplies apparently used by civilians in Canada during 1945

Foods

Foods in pounds per person per year

food group	specification	amount
dairy products (*a*)	milk solids	68
fruit :		
tomatoes and citrus	fresh equivalent	95
other fruit	„ „	77
vegetables :		
potatoes	retail weight	190
leafy, green, yellow	fresh equivalent	52
legumes (*b*)	retail weight	11
other vegetables	fresh equivalent	52
cereals	retail weight	52
meats :		
meat	carcass weight	140
poultry, game, fish	retail weight	40
eggs	fresh equivalent	39
fats and oils	fat content	37
sugars and syrups	sugar content	79
beverages	primary dist. wt.	11

(*a*) not including butter
(*b*) dried pulses, and shelled weight of nuts

Nutrients

Nutrients in units indicated per person per day

nutrient	unit	Amount
calories	—	3055
protein	grams	99
fat	„	123
carbohydrate	„	388
calcium	milligrams	1003
iron	„	14·0
vitamin A	int. units	7300
thiamine	milligrams	1·66
riboflavin	„	2·06
niacin	„	17·6
ascorbic acid	„	97

These figures are national averages and should not be taken to represent the actual supply received by each individual consumer.

THE NUTRITIONAL STATUS OF THE INDIGENOUS PEOPLES OF THE COLONIES

By B. S. Platt, C.M.G., M.Sc., Ph.D., M.B., Ch.B.

The state of nutrition of the peoples of colonial territories was reviewed in 1936 and the results were published in summary form as Part II of the Report of the Committee on Nutrition in the Colonial Empire.* Reports of investigations made between 1936 and the present time (see appendix for summary of those available to us) provide the basis for this contribution. These data, together with material in the annual reports of medical departments, have been used in drawing up tables 1–4.

TABLE I

Occurrence of nutritional deficiency disease in Colonial Territories (44 in all) 1936–1945

disease	territories reporting		notes
beriberi . .	20	Hong Kong	15,666 cases, 7,229 deaths 1940
		Malaya	1,502 deaths 1939
pellagra . .	24	Basutoland	967 cases 1943
		Hong Kong	953 cases, 442 deaths 1940
		Nigeria	413 cases 1943
stomatitis (*a*) .	8	Nigeria	3,385 cases 1938
		Uganda	1,807 cases 1936
		Mauritius	1,055 cases 1938
scurvy . .	17	Bechuanaland	619 cases 1938
		Tanganyika	167 cases 1938
		Swaziland	136 cases 1942

(*a*) Probably mainly due to vitamin B_2-complex.

* *Nutrition in the Colonial Empire*, Part II, Cmd. 6051, H.M.S.O., London, 1939.

TABLE 1 (*continued*)

disease	territories reporting	notes	
rickets . .	13	Ceylon	603 deaths 1944
goitre . .	4	high incidence Upper Gambia 1945 prevalent N. Nigeria Cameroons 1943	
nutritional (*b*) .	13	Ceylon	12,329 deaths 1944 8,379 cases of multiple 'A' and 'B' deficiency 1944
		Sierra Leone	3,153 cases 1943
		Nigeria	3,046 cases 1943
		Gold Coast	1,326 cases 1944
		Uganda	751 cases 1939

(*b*) Nutritional disease of unspecified origin reported in the 'diseases of nutrition, endocrines and rheumatism.'

The figures available are based on diagnoses made on patients attending hospitals and dispensaries ; many persons affected will not reach a doctor, and no doubt incorrect diagnoses are made and cases overlooked. Leaving aside these considerations, the main conclusions are :

(*a*) beriberi is still a common disease and cause of death in Hong Kong and Malaya ;

(*b*) pellagra is a problem in Hong Kong, Nigeria and the Gold Coast, and recently in Basutoland ;

(*c*) scurvy is not uncommonly diagnosed in Bechuanaland, Tanganyika, Northern Rhodesia and Nigeria ;

(*d*) rickets is reported from Nigeria and Aden in fair numbers ; it is given as a cause of 603 deaths in Ceylon in 1944 ;

(*e*) a large number of diagnoses of 'nutritional deficiency disease' of unspecified nature occurs in the returns of medical departments and not infrequently is given as a cause of death ; for example, 69 in the Gold Coast in 1944, 72 in British Guiana in 1943, and 90 in St Vincent in 1943.

Data are summarized in table 2 on the occurrence of diseases which may be associated with malnutrition, if malnutrition is not in some of them actually the most important cause.

TABLE 2

Occurrence of diseases partly attributable to malnutrition in Colonial Territories 1936–1945

disease	territories reporting		notes
anaemias . .	14	Mauritius	6,774 cases 1938
		Nigeria	6,632 cases 1938
		Cyprus	2,883 cases 1938
		Kenya	1,352 cases 1937
tropical ulcer . .	16	Nyasaland	28,029 cases 1944
		Uganda	26,365 cases 1936
		Gold Coast	15,921 cases 1938
infantile diarrhoea .	27	Nigeria	4,292 cases 1943
		Kenya	3,610 cases, 69 deaths 1937
		Gold Coast	3,109 cases 1944
		Uganda	2,634 cases 1939
toxaemia of pregnancy .	15	Nigeria	1,729 cases, 53 deaths 1943
		Sierra Leone	479 cases 1943
		British Guiana	19 deaths 1943
tuberculosis of the respiratory system .	38	Hong Kong	5,751 deaths 1940
		Malaya & S.S.	4,911 deaths 1939
		Ceylon	3,141 deaths 1944
		Jamaica	1,520 deaths 1943

The extent to which malnutrition affects the prevalence of these conditions is debatable ; if, however, malnutrition is admitted to be a factor the problem is, in some territories, a serious one. For example, tens of thousands of cases of tropical ulcer—a disabling disease—are reported and there must be many thousands more which have not sought treatment at hospitals or dispensaries.

Data on infant and maternal mortality rates available are set out in tables 3 and 4.

TABLE 3

INFANT MORTALITY FOR COLONIAL TERRITORIES

1936–1945

(The most recent figures available)

	deaths per 1,000 births
United Kingdom	46
Seychelles	56
Fiji	63
St Helena	63
Virgin Islands	65
Bermuda	68
St Kitts Nevis	76
St Lucia	80
Cyprus	82
Palestine	87
Montserrat	88
Nyasaland (*a*)	95
Jamaica	98
Antigua	99
Tonga	101
Gibraltar	104
St Vincent	106
Trinidad	109
Nigeria (*b*)	113
Uganda	116
Dominica	117
Bahamas	119
Gold Coast (*c*)	129
Gambia (*d*)	130
B. Honduras	130
Malaya and Straits Settlements	135
Ceylon	135
B. Guiana	141
Mauritius	163
Barbados	164
Sierra Leone (*e*)	167
N. Rhodesia (*f*)	184
Aden	197
Malta	210
Tanganyika (*g*)	243
Gilbert and Ellice Islands	246
Nigeria (*h*)	250
Zanzibar	295
Hong Kong	327

Note.—For eight territories, there are no figures available.
(*a*) eleven villages Kota-Kota district; (*b*) for Lagos only; (*c*) for Colony only; (*d*) for Bathurst only; (*e*) for Freetown only; (*f*) Chinsale area only; (*g*) a rough estimate; (*h*) approximate for whole country.

TABLE 4

MATERNAL MORTALITY FOR COLONIAL TERRITORIES
1936–1945

(The most recent figures available)

	deaths per 1,000 births
United Kingdom	2·8
St Vincent	3·0
Hong Kong	3·5
Bahamas	4·25
Mauritius	5·0
Uganda	6·25
Fiji	8·0
Malaya and Straits Settlement	9·0
Nigeria (for Lagos only)	9.25
Seychelles	11·0
Cyprus	12·0
Malta	13·25
Ceylon	13·5
Gold Coast	16·0

Note.—In thirty-three of the forty-four territories there are no figures available.

Whilst these are, for the most part, incomplete, and some are known to be inaccurate, most of them are so much higher than the level in the United Kingdom as to be a matter for real concern. It is true that besides nutritional factors there are many others which may account for high death rates in infants and mothers, but it cannot be denied that nutritional deficiency disease and high infant and maternal mortality death rates occur together. Further, good evidence is accumulating of a relationship between the state of nutrition of the newborn infant, the occurrence of complications during pregnancy, labour and delivery, and the nutrition of the mother during pregnancy. One of the clearest indications is shown in the relationship of birth-weight to the total protein in the mother's diet during pregnancy; thus recent American data* show that for boys, there is an increase in the average birth-weight from 6 lb 8 oz to 9 lb 2 oz, and for girls, from 5 lb 14 oz up to 8 lb 8 oz, as the average total protein in a mother's daily dietary rises from under 45 grams to 85 or more grams. A few reliable data on birth-weights from colonial territories have been summarized in the following table.

* Burke, B. S., Harding, V. V., and Stuart, H. C., 1943, *J. Pediat.*, **23**, 506.

TABLE 5

BIRTH-WEIGHTS IN THREE COLONIAL TERRITORIES

Nyasaland—rural area.

Average weight of 105 male infants—6 lb 11 oz
Average weight of 118 female infants—6 lb 8 oz

Malaya—Kedah estates and Penang.

Average weights of infants (both sexes) born in hospital to patients of different social groups, and different races.

social and racial group	average birth-weight	number of observations
European paying (Penang)	7 lb 3½ oz	128
Chinese paying (Penang)	6 lb 11½ oz	379
Indian paying (Penang)	6 lb 5 oz	108
(Kedah)	6 lb 4½ oz	29
Chinese non-paying (Penang)	6 lb 6 oz	2,639
Indian non-paying (Penang)	5 lb 13 oz	845
(Kedah)	5 lb 11 oz	663

Ceylon—Colombo hospital.

Average weights of Indian and Sinhalese infants born in hospital to patients of different social groups.

Paying patients	6 lb 14½ oz	216
Non-paying patients	6 lb 0 oz	2,038

These figures show that the average birth-weight increases with the social status of the mother and the birth-weights of poor Asiatic and African infants correspond with those for infants of American mothers at the lowest level (less than 45 grams) of protein intake per day.

The evidence accumulating on the effect of the state of nutrition on the mother—human and experimental animal—is so convincing that a study of the infant in colonial territories would be a most profitable subject for research. A start has already been made by a member of the staff of the Human Nutrition Research Unit, at present working on malnutrition in infants in the West Indies.

Apart from the data on the occurrence of gross deficiency disease and conditions which may, in part, be due to malnutrition, and from infant and maternal mortality figures, evidence of the state of nutrition of a population may be estimated from the occurrence and prevalence of signs

of nutritional ill-health of minor severity. These signs affect a much larger proportion of the population than gross deficiency disease, and as many as one-half to two-thirds of a sample of a population may have some of these minor manifestations of malnutrition. Recently in the West Indies, where it was rare to find fully-developed deficiency disease, some minor signs were common, as is shown in the report on Nutrition in the British West Indies.*

All these evidences of the existence of a nutritional problem may be considered together with values for the intake of individual nutrients obtained from data on food supplies. For example, data for three West Indian islands were obtained from over-all figures for food production and imports and have been evaluated on the assumption of equitable distribution throughout the population.

TABLE 6

EVALUATION OF DIETARIES OF BARBADOS, JAMAICA AND TRINIDAD

nutrient	unit	Barbados 1944	Jamaica 1942	Trinidad 1944	immediate objective
calories . .	—	2,413	2,092(*a*)	2,582	2,500
protein . .	g.	45	45	66	60
fat . . .	,,	63	32	63	—
carbohydrate . .	,,	416	406	442	—
calcium . .	mg.	254	318	306	800
iron . . .	,,	12	15	13	20
vitamin A . .	I.U.	5,215(*b*)	12,662(*c*)	4,579(*d*)	5,000
aneurin (vitamin B1)	mg.	0·78	0·94	0.98	1·50
riboflavin . .	,,	0·77	1·13	0·89	1·80
nicotinic acid .	,,	6·97	9·33	12·11	12
ascorbic acid (vitamin C)	,,	69	160	79	30

(*a*) Probably indicates a less complete return rather than an average energy intake substantially lower than the others. Incompleteness of data would, of course, affect all nutrient values.
(*b*) 208 I.U. as vitamin A, rest as carotene.
(*c*) 142 I.U. as vitamin A, rest as carotene.
(*d*) 299 I.U. as vitamin A, rest as carotene.

It will seem that supplies of some of the B2 vitamins fall short of the 'immediate objective,' and there is probably also a shortage of protein, or of certain essential amino acids. There is good agreement between the conclusions which may be drawn from the nutrient analysis of the food supplies and the prevalence of clinical evidences of nutritional status.

Only for one other territory, Malaya, has it been possible to obtain sufficiently good data on production and food imports to be able to evaluate the intake of nutrients per head of the population approximately, from

*[Nutrition in the British West Indies, 1946. Report by B. S. Platt, H.M.S.O. Colonial No. 195, fig. 1.

over-all figures for the territory. For other territories, particularly those producing the bulk of their own foods, statistics are so incomplete that it is impossible to estimate the total food supplies in this way.

Some data are available on yields of food crops grown on experimental farms or plots but reliable estimates of yields of food crops as grown by peasants are rare. The figures in table 7 will serve to show how incomplete is the information on total food production and on yields ; still less is known of the labour costs of food crops.

TABLE 7

Number of territories (possible total forty-four) providing information on local food production.
column 1—on estimated total supplies.
column 2—on yields under peasant cultivation.
column 3—on yields under experimental conditions.

food category	1	2	3
cereals	19	4	17
starchy roots and fruits	14	4	12
peas and beans	13	3	5
nuts and oil-seeds	11	2	6
meat	20	1	1
fish	14	1	1
dairy produce	13	2	1
miscellaneous fruits and vegetables	3	1	—
sugar	9	1	2

Inclusion in the above table does not mean that the figures available were exhaustive but merely that some observations of this nature had been made.

A certain amount of data has been obtained on food consumption by samples of populations, using dietary survey methods ; but this is of uneven quality. The results of food consumption studies, however, support the main conclusions as to the existence of a problem of nutrition, which have been obtained from information on the state of nutrition.

The results of several investigations made in colonial territories (summarized in table 8) afford further support for the conclusions that may be drawn from the correlation of the state of health with the nutrient content of food consumed.

TABLE 8

EXPERIMENTS TO SHOW THE EFFECT OF DIETARY SUPPLEMENTS ON THE CLINICAL CONDITION OF UNDERNOURISHED COLONIAL PEOPLES

(Numbers in brackets refer to bibliography)

experiment	result
UGANDA	
½ pint of milk per day was added to the diet of the school boys in Buganda (5).	Compared with a control group in the same school, increase in height and weight was significantly greater.

TABLE 8 (*continued*)

experiment	result
Treatment of ' kwashiorkor ' with :	
(*a*) the whole B-complex given orally as yeast or injected as liver extract.	This achieved a cure.
(*b*) nicotinic acid.	Dermatitis cleared up, varying effects on the diarrhoea ; patients worse in other respects.
(*c*) vitamin B1 (8).	Also gave varying results ; the condition is different from beri-beri.
TANGANYIKA	
Treatment of 21 school boarders (unable to see in the dark, when fresh vegetables were scarce) with vitamin A (13).	Improvement.
The effect of a better diet on patients in hospital (17).	There was an increase in haemoglobin and gain in weight of poor class patients, those with tropical ulcer highest, and those with non-specific diarrhoea and secondary anaemia the next highest.
NYASALAND	
Additions of meat and yeast to the diet of children with tropical ulcer (23).	Negative results.
NIGERIA	
Treatment of retrobulbar neuritis in school children in Southern Nigeria with Marmite or autoclaved yeast (43).	The condition yielded to treatment.
Food yeast given to lunatics and prisoners with B2 deficiency. 4–7 g. of yeast per day (46).	Striking improvements or cures were effected after 5–7 weeks.
MALTA	
Ascorbic acid given to poor children 15 months–5 years with ulcerative stomatitis containing Vincent's organism and fusiform organism (52).	Tissues returned to normal.

TABLE 8 (*continued*)

experiment	result
GIBRALTAR	
Treatment of evacuee children with gingival disease with food yeast (50).	Valuable in the treatment of some of the lesions.
PALESTINE	
900 pregnant Hebrew women, 190 with glossitis and heartburn accompanied in many cases by cheilosis, angular stomatitis and corneal vascularization, riboflavin intake 1·3 mg. per day. Treatment with :	
(*a*) riboflavin.	Rapid improvement of all symptoms.
(*b*) nicotinic acid and B_6 (61).	No effect.
MAURITIUS	
Autolysed yeast given to children with nutritional macrocytic anaemia (66).	Valuable in treating pellagrous dermatitis, angular stomatitis and glossitis.
Inter-relation of malaria, malnutrition and anaemia ; groups of children given additional foods (various, but milk, shark oil, banana, and food yeast included in some of the groups) and drugs, including quinine (65).	Feeding had a marked influence on the course of malarial infection, and the weights were improved in the children receiving additional food.
Children with crazy pavement skins given 4 mg. of B2 per day (64).	Normal in 2 weeks, and 30 per cent with angular stomatitis responded.
JAMAICA	
Oedematous babies given more milk or methionine, choline and inositol, ventriculin (103).	Oedema reduced, and liver function returned to normal. no effect no effect no effect.

It must be conceded from the foregoing evidence that there is a problem of nutrition in the colonial territories. The nature of the problem in various territories is also sufficiently well-defined for it to be possible to indicate the steps that ought to be taken to eliminate nutritional deficiency disease.

Some measures could be applied immediately with assurance that they would be effective in reducing or eliminating gross malnutrition ; for example, parboiling of rice in communities suffering from beriberi ; use of fermented foods, food yeast and skim milk powder where there is shortage of B_2 vitamins ; inclusion of red palm oil in compound vegetable oil where there is vitamin A deficiency ; use of iodized salt or increased iodine in drinking water to eliminate goitre. Many of these require the help of a food technologist in working out techniques, in applying them in tropical countries and in controlling the nutritive value of the products on the market. It is a lamentable fact that the food technologist, as such, does not exist in colonial territories.

The solution of the problem may, from the outset, require a substantial increase in production or purchase of food. In any event, as standards of living rise and populations increase in size, there will be a demand for more food and for foods, i.e. meat, milk and eggs, costly in terms of land required for production. How is an increase of food production to be achieved ? It is certain to be a complex procedure, involving the co-operation of various departments and agencies ; it needs to be carefully planned, and will be effective only by integrated effort on the part of the producer, the consumer, and technical and administrative personnel. The complexity of the problem may be gauged from the following summary* of the various factors which might be involved in increasing the amount and availability of food supplies :

PRODUCTION

(*a*) Incentives : assured markets ; desire for improved standard of living and availability of consumer goods, e.g. clothing and bicycles.

(*b*) Structure and stability of society : e.g. development of co-operative and collective enterprises ; nature and security of land tenure.

(*c*) Water : control (prevention of floods) ; conservation (protection against effects of droughts) ; utilization (irrigation, fishing and fish culture).

(*d*) Land and crops : utilization and management of land (forestry, pasture and cropping) ; soil conservation and reclamation ; varieties and balance of crops, i.e. of different food crops and of food crops in relation to cash crops ; selection of crops in relation to soil and climate ; use of fertilizers and crop residues ; improved implements including mechanized equipment.

(*e*) Livestock : balance of kinds and numbers in relation to land available for plant crops for direct human consumption ; proper use, e.g. for draught and food where still only ' currency.'

(*f*) Control of pests and diseases : e.g. locusts and tsetse fly.

* Platt, B.S. 1946. *Proc. Nutrition Soc.* **5**, 2, ' The Colonial Nutrition Problem.'

(*g*) Labour : health and efficiency ; productivity in relation to types of husbandry and individual crops.
(*h*) Trade : relation of development of natural resources to availability and ' cost ' of commodities available from external sources.

Storage, processing, transport and distribution

(*a*) Provision of buffer stocks, e.g. as communal stores to hold crop surpluses against possible failures ; production at peak seasons for surpluses for preservation.
(*b*) Protection against losses, including gross wastage and subtle losses occurring in the course of treatments and storage, e.g. control of infestation, preservation as by drying, retention of nutrients in milling cereals, enhancement of nutritive values by fermentation and improved methods of large scale cooking for collective feeding.
(*c*) Distribution : e.g. by collective feeding and provision of supplements for groups with special physiological needs.

Education

(*a*) Food habits, kitchen practices, farming methods, by means of co-ordinated and enlightened curriculae related to school feeding, school gardens, teaching of home management and hygiene ; apprenticeship systems and methods of mass adult education applied to backward countries.
(*b*) Birth control : limitation of rate of increase of population to rate of improvement of food supply.

It was agreed at the first session of the Conference of the Food and Agriculture Organization of the United Nations that one way to improve the nutrition of a group of people was by ' planned efforts to develop to the utmost, all resources within the selected area '—which requires what may be called a ' combined operation ' involving especially the agriculturalist, educationalist and administrator, as well as the medical man, nutrition expert and food technologist.

A nutrition field working party is being assembled to carry out work of this kind in West African territory, along the lines of the Nyasaland investigations. It is also proposed to set up, as an extension of the Medical Research Council's Human Nutrition Research Unit, a Field Research Station in the territory in which the nutrition field work is contemplated. The field party will make a survey of the state of nutrition of the population and factors affecting it, and of the natural resources of the area—the extent to which they have been developed and the possibilities of further development. Emphasis is being laid on the value of this project as an experiment in the application of the results of research to the improvement of nutrition. Later, it should serve as a training ground for personnel and as a working model for demonstration purposes.

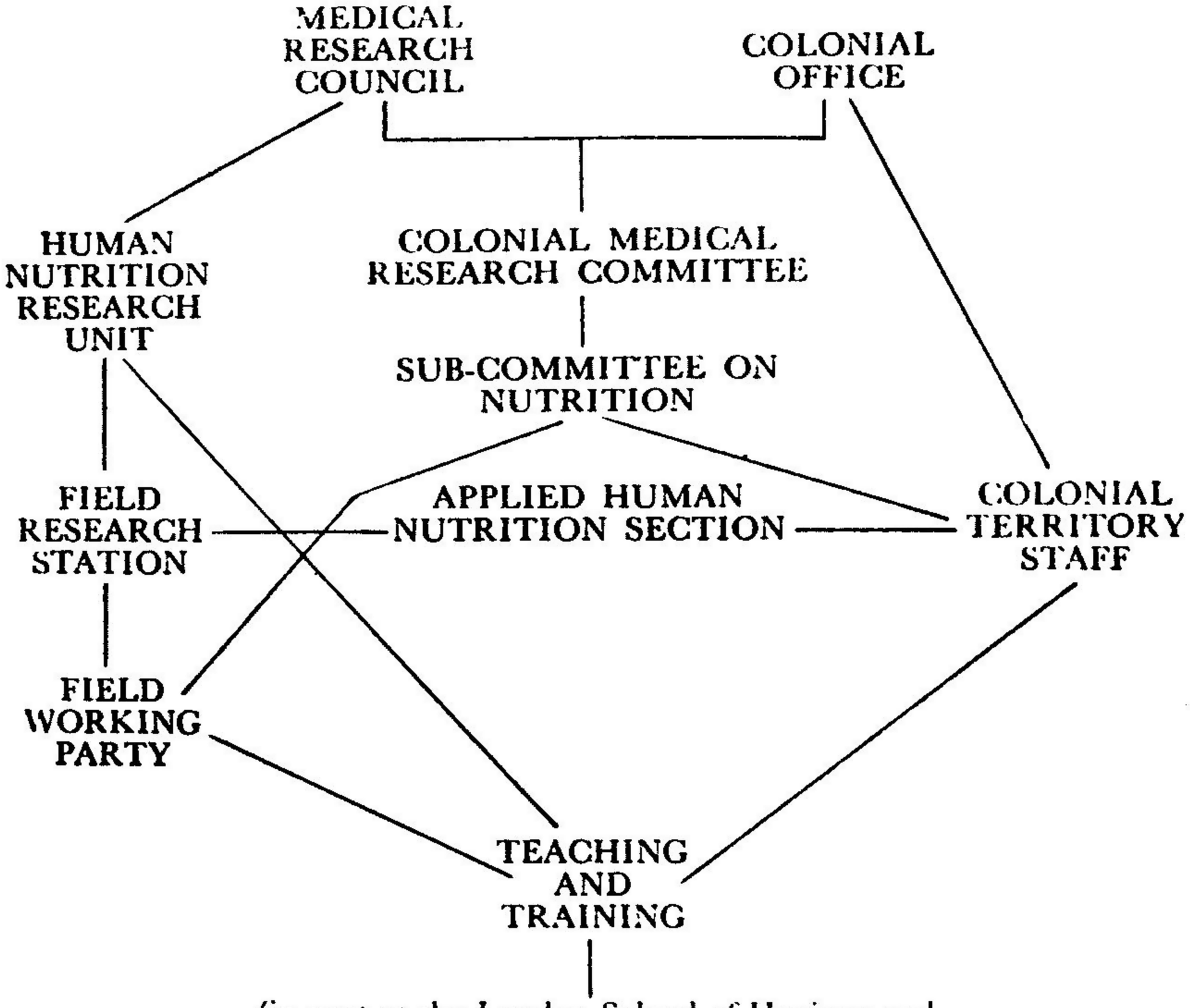
The supply of personnel for work of this kind is so limited that it is only possible at this stage to set up one organization. However, eight nutritionists, trained at the Human Nutrition Research Unit, have been allocated to various Colonial governments to carry out preliminary investigations.

Nutrition is now one of the basic subjects in courses for the diploma in public health and diploma in tropical medicine and hygiene at the London School of Hygiene and Tropical Medicine. Many of these post-graduate students take up appointments in colonial territories, so that doctors with some knowledge of nutrition are becoming available. Colonial students taking a course in social science at the London School of Economics are also given some instruction in nutrition.

During the past ten years, the importance of improving the nutritional status of the indigenous colonial peoples has been more and more appreciated at the Colonial Office. There are now nutritionists working directly from this department and there is a nutrition assistant on the staff. Governments of colonial territories can therefore be kept informed through the Colonial Office of the broad outline of scientific and technical developments.

In the colonial territories, there is no lack of interest in the problem of nutrition; in many, valuable contributions have been made towards its solution. During the war, however, governments have been preoccupied with producing sufficient food to prevent or overcome gross shortages; others have been making strenuous efforts to produce food for export to this country. But many have already made plans for the future and there is a constant stream of requests for help and information.

In the diagram below the relationships of some of the activities outlined are shown:



Attention is drawn in particular to the section on applied human nutrition which at the present time is only in an embryonic stage ; it is however certain to grow in size and importance as the need for collation of information collected in colonial territories increases and the results of work in the improvement of human nutrition become available for exchange and distribution.

The links with the Medical Research Council and the Colonial Office are shown, an important one being the Colonial Medical Research Committee—which is a joint committee of these two bodies under the chairmanship of the Secretary of the Medical Research Council—Sir Edward Mellanby.

The importance of research in the solution of colonial nutrition problems scarcely needs emphasis. Discoveries in the science of nutrition in the past have undeniably led to the present interest in the problem and continued interest is certain to depend on the stimulus which will come from discoveries in the future.

APPENDIX

SUMMARY OF NUTRITIONAL INVESTIGATIONS IN COLONIAL TERRITORIES, 1936–1945.

(Numbers in brackets refer to bibliography).

East Africa

Kenya	Analysis of post-mortem findings (1). Pellagra in adults (2). State of nutrition of African children (3). Dietary of Kikuyu (4).
Uganda	Effect of addition of milk to diet of Buganda schoolboys (5). Infantile pellagra (6). Investigations into 'kwashiorkor,' (4 papers), (7, 8, 9, 10). Dietary of Indian school children (11).
Tanganyika	Vitamin A deficiency in Africans, (2 papers), (12, 13). Crazy pavement skin (14). Physical status of Indian schoolboys (15). Diet of labourers on sisal estates (16). Effect of hospitalization on weight and haemoglobin (17). Ulanga dietary (18). Nutritional factors in Bukoba (19).
Northern Rhodesia	Food supply of the Bemba (20). State of nutrition of schoolboys in Barotseland (21).
Nyasaland	Full survey (nutrition, production and socio-economic) (22). Investigations into tropical ulcer (23). Growth and development of Bantu children (24). Dietary studies (25, 26).
Somaliland	Nil.
Zanzibar	Nil.

South African High Commission Territories

Basutoland	Nil.
Bechuanaland	Nil.
Swaziland	Investigations into local dietary habits (27).

West Africa

Gambia	Full survey preliminary to setting up of field working party (28). State of nutrition of children, (3 papers), (29, 30, 31). Vitamin B complex deficiency in native troops (32). State of nutrition of civilian population, (3 papers), (33, 34, 35). Dietary survey in government institution (36).
Gold Coast	Child health survey (37). Nutrition and dietary surveys in different areas (38, 39). Sociological survey (including diets) of one village (40).
Nigeria	Post-mortem findings on children (41). Visual acuity and avitaminosis (42). Retrobulbar neuritis and pellagra (43). B-complex deficiencies in relation to cassava as a staple (44). Cassava and cocoyam poisoning (45). Trials with food yeast (46). Dietary studies among the Ibo races (47). Crop yields and food consumed in Benue Province (48).
Sierra Leone	Nil.
St Helena	Dietary survey of families with children attending school (49).

Mediterranean

Gibraltar	Gingivitis among child evacuees (50).
Malta	Dental examinations of school children (51). Investigation into ulcerative stomatitis (52). Food consumption studies (2), (53).
Cyprus	Dental examinations of school children (54). Dietary survey of mine-workers' families (55). State of nutrition of rural school children (55). Estimates of food consumption of different income groups (55). State of nutrition of various family groups (56).
Palestine	Nutritional and economic survey (57). Clinical and dietary investigation among Bedouins (58). Clinical, dietary and economic survey among Jews (59). Investigation into serum phosphatase and clinical rickets (60). Riboflavin deficiency in pregnant Hebrew women (61).

Eastern

Aden	Clinical and dietary survey (62).
Mauritius	Clinical examination of school children (63). Treatment of 'crazy pavement skin' with B-vitamins (64). Influence of diet on course of malaria (65). Use of yeast in treatment of anaemia (66).
Seychelles	Clinical examination of school children (67).
Ceylon	Clinical examination of school children (68). Clinical and dietary survey of different groups (3), (69, 70, 71). Dietary surveys in villages (72). Cost of living survey (73). Investigations into infantile and maternal mortality (74).
Malaya	Nutrition surveys (75). Clinical surveys of school children (76, 77). Dietary surveys on estate labourers (78). Analysis of maternal and infantile mortality (79, 80). Treatment of ulcers with shark liver oil (81). Anti-neuritic values of parboiled and undermilled rice (82). Clinical, dietary and agriculture surveys following re-occupation at end of war (83, 84). Observations in internment camps (85).
Sarawak	Nil.
North Borneo	Nil.
Hong Kong	Dietary surveys (86, 87). Infantile beri beri (88). Nutritional amblyopia (89). B-complex deficiencies (90). Observations in internment camps (91).

West Indies

Whole area	(with special reference to Barbados, Jamaica and Trinidad). Combined clinical survey and estimate of food supply, together with recommendations for immediate measures and long-term policy (92).
Bahamas	Nil.
Barbados	Examinations of school children (93).
Bermuda	Examinations of school children (94). Food consumption, local production, estimated requirements (95).

	WEST INDIES (*continued*)
BRITISH GUIANA	Cost of living survey (96). Malnutrition among dispensary patients (97). Review of institutional dietaries (98). Clinical survey of Akowoio Indians (99).
BRITISH HONDURAS	Nil.
JAMAICA	Dietary and economic survey (100). Inquiry into causes of vomiting sickness (101). Review of food supply position (102). Nutritional oedema in infants (103).
LEEWARD ISLANDS	Nil.
TRINIDAD	Dietary survey among oil field labourers (104, 105). Use of milk during pregnancy and for infants (106).
WINDWARDS	Health and social survey of school children (Grenada), (107). Cost of living survey (St Vincent), (108).
	WESTERN PACIFIC
FIJI	Cost of living study on Indian workers (109).
GILBERT AND ELLICE ISLANDS	Nil.
NEW HEBRIDES	Nil.
SOLOMON ISLANDS	Nil.
TONGA	Nil.
	SOUTH ATLANTIC
FALKLAND ISLANDS	Nil.
TRISTAN DA CUNHA	Nil.

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THE POLICY OF FULL PRODUCTION IN COLONIAL AGRICULTURE

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I AM greatly encouraged that the subject of a policy of full production in Colonial Agriculture has been brought before such a conference as this, for I have served the Colonial peoples in East Africa and the West Indies for over twenty years and, despite the new Colonial outlook and the new attitudes to dependent peoples, I am still filled with anxiety as to the future. The problem is one of 60,000,000 people, the greater part of whom are living under primitive conditions, on or near a bare subsistence basis. Such a level can be endured only by those people who are completely insulated from western standards of life. Such communities no longer exist in the British Empire to-day : the war has broken down every barrier of communication to the mind, and has left us badly unprepared to meet the situation. Clearly nothing but the fullest possible development of the material and human resources of the Colonies, primarily to ensure the progress of each, will satisfy the undeniable aspirations of the people concerned. I believe that science, with present knowledge, can provide a sound basis for the required policies of full production. But time is short.

However competent science may be to lay down principles and to provide facts as a basis for policy, and however ready Colonial Administrators may be to agree with them, no policy can hope to succeed unless it is understood and accepted by the people. It is almost as bad to have no policy at all as to endeavour to superimpose a ready-made one on any Colony to-day. I think it would be helpful, therefore, if we could get some idea of what a politically advanced Colony is likely to accept. Fortunately, we have an example in the recently published Report of the Agricultural Policy Committee of Jamaica. The Committee is probably unique, as far as the Colonies are concerned, in the fact that its members were not Government selected men. Sir John Huggins, the Governor of Jamaica, invited the principal organizations, such as the Agricultural Society, commodity associations, trade unions, welfare agency, chamber of commerce, and the Legislature each to name their own representative. I was invited to be Chairman. Our deliberations were exhaustive, in more respects than one, and we took full advantage of all available scientific and technical advice ; fortunately Dr Platt was visiting the island at the time and gave us a most valuable address.

Despite the apparently conflicting interests, and the divergent views previously held by its members, the Committee presented a report which, with a small note of reservation by one member, was unanimous. Its recommendations were well received throughout Jamaica, and gave satis-

faction to the Sugar Manufacturers' Association and the People's National Party alike. The policy formulated by this highly political Committee of non-officials amounted to one of full production. The report outlined the conditions which must exist, the steps to be taken, and such controls as the Committee considered to be essential to achieve the aims of policy.

It was necessary first to draw a clear distinction between policy and planning. The Committee held that policy should be primarily concerned with the basic social and economic aims of any given activity and should lay down the conditions which must exist for any given policy to succeed. They considered that planning is a matter for experts and has regard to how those aims are to be secured. It was pointed out that agricultural policy must be conditioned by social and economic policy as expressed at the highest political level. They recognized that agricultural policy must always have regard to the inescapable laws of nature ; the scope and methods of production must harmonize with nature, so that soil-fertility may be built up and not destroyed as in the past.

So often, so much is said and decided with little or no facts to go on ; and rarely are reliable data of land use to be found in the Colonies. Fortunately, we had the advantage of a very complete census of Jamaica made in 1943 by Mr Pelletier, of the Canadian Government Service. It dealt with land use as well as population, from which we were able to prepare a balance sheet of Jamaica's land resources. We applied this to the primary needs of the people, particularly in regard to nutrition. Analysis of the figures destroyed a number of fallacies ; for example, the notion that there were large reserves of good unused land was shown to be illusory ; this in itself is of great political importance, for it brought the question of land settlement down from the realms of sentiment to a basis of fact. It was shown that there was far more land producing for local use than for export purposes. Only one person was engaged in agriculture for little over every five acres of farmland. The average output per person amounted to not more than £66 in gross value, or about £10 per person. It was obviously essential that these production figures be increased ; and that increased mechanization is inevitable if this is to be done. It was also clear that the basic development of the land and water resources provided the best opportunities for employment, particularly with urgently required soil-conservation works. The Committee was so impressed with the value of the statistical data that it asked for the foundation work of the 1943 census to be continued by a permanent Bureau of Statistics.

The basic objective of agricultural policy was held to be the achievement and maintenance of a reasonable standard of living for all people, with the possibility of providing for a progressive increase. This inevitably carries with it a policy of full production with three major purposes to which the use of land must be put : namely, the production of food for local consumption ; the maintenance and extension of export products, and the provision of raw materials for local industry. Here I would quote verbatim from the report itself, as follows :

> ' We stress the importance of achieving the best economic balance between the three purposes, because of such obvious considerations as the fact that there are certain foods, particularly cereals, which

> are essential in Jamaica but which Jamaica is unable or unsuited to produce, and so must import. On the other hand we take the view that it can never be right, either economically or socially, to allow usable land of the island to remain idle whilst there are people unoccupied. We hold this view since it cannot be accepted that reasonable standards of living can be maintained unless continued attention is given to, and equal emphasis placed on, the use of land for all three basic purposes.'

The real question which the Committee put to the people of Jamaica was not whether the main objective of policy was desirable, but how far the country would be prepared to go in order to achieve the desired end, by such means as establishing and submitting to controls, providing finance for capital development, incentive payments and the like, regulating imports, organizing marketing and providing price guarantees.

The conditions which must exist for a policy of full production to succeed in Jamaica are stated in the report. The principal being the rehabilitation of land already damaged by misuse ; the adoption of measures to improve soil-fertility ; ensuring that land is used for those crops for which it is best suited ; the determination and adoption of efficient methods to reduce costs and increase yields ; and security of land-tenure. Other relevant factors are the creation of confidence in agriculture, by recognition on the part of the public of the necessity of a long-term basic policy, also definition by the State as to the steps it will take to secure the implementation of policy and to maintain the economic stability of the farming community. Lastly, to use the words of the report, ' acceptance on the part of United Kingdom Governments of responsibility for a long-term policy relative to stable markets and prices for Jamaican export crops.'

The Committee recognized that the main objectives of agricultural policy could not be achieved without some measure of control. They came out strongly for the establishment of a Land Authority, which would have to deal with two aspects of the problem : first the need to devise the means for bringing all land into proper use, and second, to secure efficient use of it in close relation to the aims of policy itself.

Acting on the Committee's recommendations, the Jamaica Government has already enacted laws for tenancy reform and marketing.

The subject of finance, capital and credit was one of the most difficult and important. It has to be frankly recognized that individual farmers in Jamaica, and indeed throughout the West Indies, cannot undertake the double burden of all the capital expenditure needed for basic development, and the rapid adoption of new farming systems. Much land is already ruinate, and most of it is badly run down. The Jamaican picture is one of decreasing productivity of land, with ever increasing expenditure to remedy that condition, and of a rapidly increasing population with increasing demands for the products of the soil. A solution to the problems of finance is vital, and considering the complexity and highly technical nature of the subject, the Committee considered that the services of a financial authority be obtained from New Zealand, where they appear to have rationalized the difficulties of agricultural finance better than most countries. I should mention here that a Colonial Development and

Welfare grant of half a million pounds for incentive payments to farmers was made last year to Jamaica.

The Committee recognized that an agricultural revolution was necessary in Jamaica if the objective of policy is to be achieved ; it can be claimed that this has got well under way during the past two years. Nevertheless, although the past systems of monoculture were harmful, there are exceptions in as far as the purely agronomic aspect is concerned, e.g., sugarcane is a soil-conserving crop which can be grown almost indefinitely on the same land, then permanent orchard crops are required in high rainfall mountainous areas. Generally speaking, however, whether regard is given either to the need for soil-conservation, or to nutrition, or to the economic stability of farmers, or to the encouragement of family life as a secure and stable institution, or to a more even distribution of labour throughout the year, the Committee decided that mixed farming is the most suitable system for the small and medium scale farmer.

The provision of water for farm as well as for domestic use was urged as an absolute priority, adding permanently to the real wealth of the country. In regard to housing, it was obvious from the census data on the subject, that Jamaica could never hope to improve the present deplorable position unless every local resource was developed for house building.

The Committee did not ignore the need for research. On the contrary, they realized that well-planned and properly equipped research programmes were required for all branches of agriculture and animal husbandry, including the preservation and storage of foodstuffs of which there is great out-of-season waste. As to the cost, they pointed out that millions of pounds have been lost and great losses are still suffered from Panama and leaf-spot diseases of bananas alone, and from contagious abortion, mammitis and tuberculosis in cattle. They want producers to be associated, through their associations, with the planning, conduct and application of the results of research. They recommended that the Government of Jamaica should provide machinery for keeping in touch with all resaerch work to ascertain and develop new and extended uses for the products of tropical agriculture. I may say that any research organization that wishes to send its workers to carry out investigations in Jamaica, will find both a welcome and every endeavour to provide them with the necessary facilities.

As for education, it was obvious that Jamaica could not afford to provide the usual courses in agriculture to many people. The Danish Folk School system, which enables relatively large numbers of young men and women to be trained and returned to their respective communities was preferable, together with 4-H Clubs for the young, and a system of adult education related to the agricultural extension services.

Coming now to production policy itself, the Jamaica Committee found that the attainment of an economic balance between the three purposes of land use in Jamaica were in general accord with the recommendations of the 1943 Hot Springs Food Conference. At the same time, the Committee felt it was necessary to state the obvious, that imports have to be paid for, and the main source of payment is the export trade. In Jamaica there is a large gap between the value of exports and the cost of imports. The situation cannot be met by concentrating on exports alone, or unduly

concentrating on production for local use. What is needed is the full use of all agricultural land, with a considerable increase in yields and output from all branches of agriculture.

As far as the export trade is concerned, only some of the essentials to its maintenance are within local control. Others are dependent on British and International policies. The principal essentials of production for export are stability of markets and long-term price guarantees, together with organization of producers with the dual aim of more efficient production and marketing, and of securing effective representation abroad of Jamaica's position and needs. The one thing that is absolutely certain is that Jamaica can never achieve agricultural efficiency without stable markets at fair prices for her export commodities. Without them the position of the whole of the West Indies is bleak.

As to food production for local consumption, a national minimum diet was worked out by Dr Platt. From this we determined the acreages required for the different crops to produce that diet, and balanced this with our available land resources. We found that the Platt diet, which was designed to be an immediately attainable minimum, could be produced locally by present methods, except for half the cereals ; the areas suitable for rice being limited, and the high rainfall conditions being unsuitable for most other grains. The development of dairying which is an essential part of land use under Jamaica conditions would enable this minimum diet to be supplemented by milk and meat to suit different social demands.

The requisites for increasing the local food resources, and improving the diet of the people, were held to be :—

(*a*) Control of imports, and the setting up of pools where necessary. The establishment of an Import and Price Control Board was recommended.
(*b*) Controlled prices.
(*c*) Subsidies in the early years of development of a particular produce where this is of importance to the Colony's nutritional needs.
(*d*) Application of the techniques of mass education to nutrition.
(*e*) School meals to serve the double purpose of education in the use of new foods, and a progressive improvement in nutritional standards. Such a provision by government would be an indirect way of subsidizing and encouraging mixed-farming.
(*f*) Improvement in the collection, storage and processing of food for home use.

In regard to production for industrial use, the main hope for this in Jamaica lies in the work of the Colonial Products Research Council, under Dr Simonsen, particularly that on carbohydrates by Professor Haworth of Birmingham University.

The policy for full production as advocated above has now to be debated in the House of Representatives. There is no doubt that if the House accepts the policy, the Jamaican farmer will be able to plan his future operations with confidence, he will enjoy a sense of security which has been lacking hitherto. But there is that which is outside local control ; in the words of the Jamaica Committee, ' while the signatories of the Final Act of the Hot Springs Conference reiterate their desire to improve the

local conditions of backward countries, this can never be achieved unless guaranteed markets are provided for primary commodities at prices which enable producers to pay reasonable wages, to earn a fair living, and to improve their production methods.'

That is a brief description of the making and content of a policy of full production in the agriculture of the Colony of Jamaica. There may be gaps in it that have to be filled ; undoubtedly adjustments will be required from time to time. But the great value of the Report is the fact that from first to last it is a Jamaican Report, and no proposals coming from outside, or which may be prepared solely by officials from overseas, will get nearly as far as Jamaica's own plan.

Finally, although no great future is possible to Jamaica unless she is able to export a considerable amount of agricultural produce at remunerative prices, her people are determined to feed and house themselves to the fullest possible extent from their own local resources, whatever the state of the world's markets may be.

It is along these lines, I suggest, that the success of a full-production policy can be most surely achieved. It is in that way that a colony can build itself up to the status of an independent nation.

MORNING SUBJECT (d)

DISCUSSION OF MODERN METHODS OF MAPPING AND EXPLORATION BY AIR, INCLUDING THE USE OF RADIO TECHNIQUE IN ORDNANCE SURVEY WITH SPECIAL REFERENCE TO PARTICULAR PARTS OF THE EMPIRE

STEERING GROUP

Chairman—Dr E. S. Moore

Recorder—Lieut.-Colonel C. A. Hart

Dr E. C. Bullard, F.R.S.
Major W. R. Junner
Dr M. S. Krishnan
Sir John Madsen
Professor B. F. J. Schonland, F.R.S.

REPORT

This discussion was occasioned by the fundamental change in the scientific approach to surveying which had been the result of the application of radar to mapping at the Directorate of Military Survey, War Office, during the recent war.

The Conference recognized that considerable areas of the Commonwealth were still unmapped or covered only by rough reconnaissance maps. The rapid extension of reliable mapping was of great importance as a basis for sound economic development. Large unmapped tracts in the north-west of Canada in particular contained great and varied mineral deposits which could not be exploited until accurate maps became available.

After the war of 1914–1918 the development of methods of surveying from air photographs enabled accurate maps to be made much faster than by ground methods alone. Much work remained to be done on the ground, however, since no means was available for establishing scale on air photographs without the provision of a system of points whose positions in relation to the earth's surface were known and could be identified on the photographs. Only then could topography be interpreted and plotted. The provision of a complete geodetic triangulation extended to secondary and tertiary systems and with additional points fixed for scaling and heighting from air photographs was expensive in time and money. This was particularly so in undeveloped areas. As a result of experimental work carried out during the war there was now an alternative to this method and an informative account of it was the main feature of the discussion. The successful application of the new methods would affect methods of surveying to a degree comparable with the effects of the original application of air photography. This would apply not only to air survey but also to primary triangulation.

The technique depended on the use of the radar navigational aids developed for precise bombing. These methods enabled the photographic aircraft to be navigated along the desired track and its position at the instant of photography to be determined in relation to a pair of remote radar stations at present up to 250 miles distant from the plane.

The accuracy of navigation by the radar control of flight-lines in a predetermined flying programme provided remarkable economies in the time and materials required for covering an area with survey photographs.

Moreover reasonably accurate topographical maps up to a scale of 1–25,000 could be made with no access to the ground other than the control provided by the geodetic fixation of the remote radar ground stations. This was especially useful in the surveying of territories in which access to ground was either difficult or impossible. For precise mapping it was still necessary to have some ground control but very much less than before.

Experimental maps of several areas in Great Britain had been made by this method. These were shown during the discussion in comparison with maps made by the usual methods. The agreement was close enough to leave no doubt that the method had very considerable application to topographical mapping.

Radar control was now being employed for air survey work in the West African Colonies where, on account of tropical forests and orchard bush, ground surveys were particularly laborious.

It was stated that radar methods of ranging long lines were already achieving an accuracy approaching 1 part in 30,000 and that this would make possible direct connexions over wide gaps up to 500 miles which previously could only be done less accurately by astronomical methods. It was emphasized, however, that the work so far carried out had been of an experimental nature and that much research and development was required before full advantage could be taken of the new methods.

During the general discussion senior military officers emphasized the great advantages that would have been afforded by the employment of these new methods during the war. The incentive for their development up to the present had been the need to devise a means of making military maps of countries such as Siam and Indo-China under enemy occupation and where no effective access to the ground was possible for the Allies. The importance of further research and development on the application of radio techniques to surveying for economic development within the Commonwealth was emphasized by several speakers.

General statement

The Conference agreed that the use of radar would much reduce the time required for the making of maps. In view of the importance of completing the topographical mapping of various parts of the Commonwealth for the purpose of economic development, the Conference put forward the following :—

Recommendations

1. Research and development in radar and photographic equipment and techniques in air survey should be vigorously pursued, if the full scientific and economic advantages of these methods are to be obtained in all parts of the Commonwealth.
2. The appropriate authorities should be approached with a view to increasing the number of persons trained to conduct further research in these subjects.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Sir Lewis Fermor

Sir Lewis Fermor said that he would not like the remarks of his friend Professor Saha to create a wrong impression concerning the quality of the maps produced by the Survey of India. As an officer of the Geological Survey of India, he had used them for over thirty years and could thus speak from experience. A large proportion of India had been surveyed on the scale of 1″ = 1 mile. In the older maps the relief was indicated by hill shading, and the heights were given at scattered points. Some of these maps would not be suitable for Professor Saha's purposes. But in the new 1 inch maps made during the present century, hill shading was replaced by 50 foot contours ; and for accuracy and detail these maps were probably equal to those of any other country in the world. Periodic financial stringency had delayed the execution of this new programme, but for very large tracts of India the new maps had already been finished.

In addition there were the maps of the scale of 4 miles = 1 inch of the Reserved Forests. In these maps the contours were at 25 foot intervals, and the actual height was shown at many points on each sheet. This made easy the work of the geologist, even in thick forest. He (Sir Lewis), by the use of an aneroid barometer and his own scale of hourly corrections for diurnal variation, was able at any moment to determine the height of any spot, and such determinations were usually within 10 feet of the heights shown on the map. Had any other country in the British Commonwealth maps upon which this could be done? The answer is probably 'No.' For though the maps of the United Kingdom have the necessary orographical details, the weather in this country did not behave with the regularity that characterized a cold-weather day in India !

LEGAL SURVEYS AND MAP SERVICE IN CANADA

RESEARCH WORK UNDERTAKEN IN THE PAST

Direction finding charts

For use with radio direction finding stations, a D/F chart was constructed on the gnomonic projection. A protractor calculated to measure true azimuth from each D/F station was added to the chart. In addition, the margin of the chart was divided into 98 divisions, each measuring one inch and subdivided into tenths of an inch. At each D/F station the observed azimuths may be plotted by means of the local protractor or by means of a table of marginal co-ordinates made up for each station. Various revisions of the chart were made as changes in D/F stations occurred.

Drift sight

A device based on perspectometric principles, whereby horizontal distances to natural features from an aircraft could be measured and sketched and ground speed determined.

Camera sight

A device on the camera obscura principle, whereby the time interval for any desired forward overlap of vertical photography could be determined.

Manual for astronomic observations

Research in practical field astronomy resulting in a manual for the determination of time, latitude and azimuth on the sun and stars.

Trimetrogon photogrammetry

Research resulting in nomograms on glass or plexiglass for reading off depression angles, dip and interlocks. For corrections in both directions for print distortion. For checking the scale of paper templet assembly at any desired templet base. For reading off depression angles and interlocks for any measured print size, and the corrections to measured interlocks and depression angles. Graph for the solution of formula transposing tip in the oblique plane to its horizontal equivalent, for all-over depression angles.

Research resulting in a rapid graphical method for adjusting all resected points to proportionally mean positions, necessitated by failure of coincidence of the same feature tie points of adjacent photo flights.

RESEARCH WORK NOW UNDER WAY

Aeronautical charts

For the past number of years there has been research in co-operation with the R.C.A.F. and the Civil Aviation Division of the Department of Transport in the development of the different types of aeronautical charts to meet practical conditions peculiar to Canada and for the general needs of safe international aviation. The selection of topographic details and air navigation aids and their presentation in a clear and concise manner on the charts are matters for continuing study.

Heights

There is a great lack of ground elevations in Canada, particularly over the northern unmapped areas. In an effort to arrive at a quick and efficient method of spreading a large number of spot elevations over the country from which to draw approximate contours on the air navigation charts some experiments with the terrain clearance indicator (AN-APN-1) and a sensitive altimeter were made, the sensitive altimeter providing the elevation of the plane above sea-level and the terrain clearance indicator measuring the distance from the plane to the ground. Results were satisfactory over water areas, the elevations of the water surfaces determined indicating an accuracy of ± 30 feet, but over rolling wooded country measurements were erratic and showed discrepancies as large as two or three hundred feet. The experiments have been discontinued but may be revived if and when a more efficient terrain clearance indicator or radio altimeter is available.

RESEARCH WORK CONTEMPLATED FOR THE FUTURE

Rheostat-controlled camera sight for forward overlap

Research report was made for the construction of an automatic precision forward overlap exposure instrument. A band travels over the exposed ground glass of a camera sight. The band has periodic markers in contact with the ground glass. A rheostat governs the speed of the band, so that the marker is made to travel at the same rate as the imagery over the ground glass. The spindle shaft carries a wheel with a contact point, of diameter suitable to make contact at the desired per cent forward overlap, thus exposing the camera. This report was favourably received, but the instrument has not yet been constructed.

Photography of horizons

An idea for research is submitted for the installation of a 35 mm. telephoto camera to photograph the horizon for trimetrogon and vertical photography. If the telephoto camera is geometrically related to the mapping camera, and if both cameras are simultaneously exposed, the nadir may be speedily determined from suitable calibrating scales in respect of the horizon. The possibilities of infra red emulsion for the 35 mm. camera are suggested.

MAPPING IN CANADA

CANADA is a country with an area of 3,695,189 square miles. Its eastern extremity is in west longitude 57° and its western extremity is in west longitude 141°. The southern point is in north latitude 41° 41′, and from there it extends to the north pole. Canada has 49,470 miles of coast line. The population in 1941 was 11,506,655 and is now commonly said to be twelve million.

From a mapping point of view it is essential to have a brief and general picture of the physical geography of the country which falls into six natural divisions :

1. THE APPALACHIAN AND ACADIAN REGIONS

This is a beautiful part of eastern Canada, of diversified mountains and hills interspersed with areas of good farmland.

2. THE ST LAWRENCE REGION

This is the extensive depression containing the Great Lakes and the St Lawrence River comprising about 35,000 square miles. This area contains the greater part of the population of Canada and is the area of greatest industrial importance.

3. THE CANADIAN SHIELD

This includes more than 50 per cent of the mainland area of Canada. Only small areas rise over 2,000 feet above sea-level, but the surface is greatly cut up with countless lakes and streams. Minerals and timber are the chief resources. In 1939, 85 per cent of the gold, 87 per cent of the copper and all of the nickel, radium, platinum and cobalt produced in Canada came from this area.

4. INTERIOR PLAIN

This is part of the great plains regions in the interior of the North American Continent extending from the Gulf of Mexico to the Arctic Ocean. In Canada, from an elevation of 3,400 feet at Calgary, just east of the Rocky Mountains, the interior plains slope gradually eastward for 700 miles to an elevation of 800 feet where it meets the Canadian Shield at Lake Winnipeg.

5. THE CORDILLERAN REGION

This region extending inland from the Pacific Ocean for about 400 miles, has an area of 530,000 square miles. From sea-level it reaches an extreme elevation of 19,850 feet and is the most rugged in Canada.

6. THE ARCTIC ARCHIPELAGO

This triangle of islands, of which the three largest have an area of over 357,000 square miles, extends from the mainland of the North American

Continent to an apex in Ellesmere Island in north latitude 83° 30'. It lies entirely in the Arctic Ocean.

Obviously a young country with as diversified a physical geography as in Canada, requires a variety of maps and mapping methods. The main objective is to produce maps essential to the development of the natural resources, including the large part that air transport and reconnaissance plays in the discovery and development of these resources. Also having a bearing on map needs and methods is the situation where the population is largely concentrated in the southern part of Canada which includes the St Lawrence Lowlands, the Appalachian and Acadian regions and the southern fringe of the Canadian Shield, the Interior Plains and the Cordilleran Region.

Mapping in Canada is now carried out by the Department of Mines and Resources and by the Department of National Defence. In the former all original mapping for the development of the natural resources is carried out by the Topographical Survey. This includes mapping on the standard scales of 1, 2 and 4 miles to the inch as well as special maps on larger scales. Hydrographic charts on various scales and air charts on 8 and 16 miles to the inch are prepared by the Hydrographic and Map Service in the Department of Mines and Resources. Standard maps on 1 inch to 1 mile are also made from original surveys by the Geographical Section General Staff of the Department of National Defence.

With its vast unmapped areas and the present necessity for rapid progress in providing base maps for the development of our natural resources, Canada is greatly interested in the application of radar control. To this end the Associate Committee on Survey Research is actively pressing the research and the application to Canadian needs. The problem is being studied by a Committee composed of representatives from the Royal Canadian Air Force, the Army, the National Research Council and the Mapping Branches of the Department of Mines and Resources. It is hoped that the necessary equipment can be secured and experiments carried out in 1947.

With radar control for the photographic flying goes the problem of plotting the resultant air pictures. Multiplex seems to be the answer and plotting by this method will be carried out as a part of the investigation. The plotting will be done under the direction of the above Committee, using Army personnel with overseas training and experience in this work and providing training of civilian personnel of the Mapping Branch of the Department of Mines and Resources.

In any memorandum on, or discussion of, Canadian methods of mapping it must be clearly kept in mind that stereophotogrammetric and ground methods are now so closely intertwined that both are an essential part of all map production. The amount of information taken from the air photographs and the amount secured by ground methods varies for different scales, different types of country and varying density of detail to be shown, but it is a general principle that both are used in every map produced.

Standard mapping in Canada conforms to the National Topographical System of sheet numbering. The unit is 4° in latitude by 8° in longitude and as a 1-inch to 16-mile map would be issued as an Air Navigational chart with a number, for instance 43. Each 16-mile sheet is quartered into

sheets 1 inch to 8 miles which are numbered by quadrants, e.g., 43 NW. Each 16-mile sheet is divided into sixteen 1-inch to 4-mile sheets 1° latitude and 2° longitude which are lettered from A to P, starting from the SE. corner, e.g., 43 G. Each 4-mile sheet is quartered and numbered according to the quadrant, e.g., 43 A/NW. Each 4-mile sheet is divided into sixteen 1-inch to 1-mile sheets 15′ latitude and 30′ longitude and numbered from 1 to 16 starting from the SE. corner, e.g. 43 A/7.

All field work is regarded as control for air photographs. In Canada the broad control for mapping is a function of the Geodetic Service. For many of the remote areas where present needs call for 4 and 8 inches to the mile, work triangulation data is not available and the control for these maps has to be provided by other means.

For the 4 and 8 inches to 1-mile scales it has been found that astronomical fixations provide satisfactory control. For the 8-mile scale these are spaced approximately 50 miles apart and for the 4-mile scale the spacing is 25 miles. Using the 45° astrolabe method a minimum of 16 stars are observed, with time by radio signals. The mean average error of the astronomical observations has been found to be 100′. The deflection of the vertical may in certain areas introduce a factor which is still uncertain but on which the Geodetic Services continues to accumulate data.

For 4-mile mapping where contours are required, which to date has been in the mountainous regions, triangulation and ground photography are used for control. The ground photographs are taken from the triangulation stations and both supplement and control the air photographs. For 4-mile mapping where planimetry only is required, control may be needed and is secured by either or both triangulation and traverse. The choice or combination depends on the nature of the terrain.

For scales larger than the 4-mile, the triangulation and/or traverse control is carried out by field parties, the method depending on the nature of the terrain and the scale of the required map.

In 1-inch to 4- and 8-mile mapping trimetrogon photography is needed. This is a three-camera assembly with one vertical and two wing obliques giving horizon to horizon coverage. The usual altitude for this photography is 20,000 feet with flight lines 20 miles apart. For 8-mile maps the plotting technique developed by the Americans during the war is followed, but for 4-mile work modifications have been introduced.

Since air photography in Canada has to serve various needs such as mapping, forestry, agriculture, geology and administration it is necessary to have a large programme of vertical photography. The present programme calls for 200,000 square miles per year.

NOTE ON MAPPING AND AERIAL SURVEY IN NEW ZEALAND

By R. G. Dick

GEODETIC TRIANGULATION

A GEODETIC triangulation carried out in accordance with standards prescribed by the International Union of Geodesy and Geophysics was commenced in New Zealand under the direction of the Surveyor-General in 1911, and at the outbreak of the world conflict was nearing completion.

The equipment employed is of the standard and type employed by other countries for this class of work. Wireless communication was employed for the purpose of contact between the observer and the light-keepers stationed at the various signals. By this means daily instructions can be issued, avoiding the long delays caused by visual signalling or land wire communication.

The final results of this work will enable geodesists to determine more accurately the shape of the earth from a measurement of an arc in the South Pacific area.

TOPOGRAPHICAL MAPPING

The use of the aerial photograph for the production of topographical maps has greatly advanced the science of topographical mapping. The Dominion of New Zealand is completely netted with a third-order plane triangulation, numerous standard traverses and a land boundary survey system related by plane co-ordinates to circuit initials.

This provides an excellent planimetric control for the plotting of topographical data from vertical aerial photographs. Features such as boundary fences, roads and trigonometrical stations can be identified on the photograph, thus forming the control for subsequent detailed plotting.

Experience in the Dominion has proved that when high standard photography is combined with the horizontal survey control provided by the survey system of the Dominion, the use of mechanical plotting equipment to provide for the bridging of uncontrolled areas is reduced to a minimum.

Aerial photography in New Zealand has been carried out by a private operating company. Tip and tilt factors in vertical photography have been reduced to a minimum and in no case exceeds 3 per cent. This high grade of accuracy in the initial photography reduces the subsequent amount of plotting work.

THE USE OF AIR PHOTOGRAPHS FOR FOREST SURVEY IN CANADA

DOMINION FOREST SERVICE

IN Canada the Dominion Forest Service, Lands, Parks and Forests Branch, Department of Mines and Resources, Ottawa, uses air photographs for forest survey purposes on federally administered lands and has also used them, in special instances, on provincial lands. Research is being conducted along with the practical work and a technique is being established that is facilitating the use of air photographs for forestry purposes.

Possibly the most important advances that have been made are in relation to the volumetric estimating of the timber stands. The air photograph brings with it a new approach to the problem of timber estimating, in which the height of the trees, sometimes supplemented by crown diameters, takes the place of the bole diameters as usually measured on the ground. Also the comprehensive view provided by the air photograph enables the spacing of the tree crowns to be determined to great advantage throughout the whole forest, as compared to the laborious counting of trees on limited sample areas on the ground.

In developing the technique of volumetric estimating, the Dominion Forest Service introduced the shadow method of determining tree heights and originated the grids that are used to ascertain tree heights in oblique photographs. Incidentally, these two methods, which had received their main development for forestry purposes, were subsequently applied to very good effect for war purposes and particularly the shadow method became a most important aid in the determining of the heights of various structures in enemy terrain as required for intelligence purposes.

The displacement method of determining tree heights, by which the image of the tree is measured in a single vertical photograph, is also important in the technique of the Dominion Forest Service. Elsewhere, the British Columbia Forest Branch has applied the method of stereoscopic parallax and has thereby done considerable work in the development of a technique for the determination of tree heights by means of the ' floating mark.'

' Intensity ' data are obtained from sample areas on the ground and are tabulated to show timber quantities in accordance with the height and crown density that have been determined from the photographs, thus enabling the volumetric estimates to be made. These data are used when dealing with the stand of timber as a whole, but sometimes the estimate of wood quantities is prepared from individual sample trees as in ground work. Also a method has been developed based on the characteristics of tree growth, by which the diameter of the bole may be estimated from the tree's height and crown diameter as determined from the photograph.

The savings effected by means of volumetric estimating from air photo-

graphs are becoming increasingly recognized. The degree of accuracy of air estimates like that of ground estimates, is, of course, dependent on the available data. In the case of the air estimates these data consist mainly of tree heights, crown densities, and 'intensity' figures, all except the last named being in turn dependent on the degree of detail supplied by the photograph, which varies with the scale of the photograph, the season of the year and nature of the forest.

The season of the year has a profound effect in regard to volumetric estimating. The shedding of the foliage of deciduous trees in the fall makes possible a greatly augmented view of both trees and shadows which lasts until the coming of the new leaves in the spring. Snow forms a smooth, bright surface upon which the shadows are sharply cast and by which the detail in the depths of the stands is illuminated and accentuated.

A forest survey does not consist of timber estimates alone and much information relating to species, age, site and defective timber, is not available from the photographs and must be obtained by ground work. While hardwoods can usually be distinguished from softwoods except in certain midsummer photographs, a further differentiation of species presents difficulties. These may, however, sometimes be solved by a process of elimination in cases where very few species are present; by the aid of site classification from air photographs, by knowledge of the forest associations and successions; by shape and texture of crown; by tone of foliage, particularly in the autumn; by phenological distinctions; and by the use of special films and filters.

Not only does air photography make possible a forest inventory in a manner unattainable by ground work, but also it makes practicable the maintenance of the inventory in a fairly up-to-date condition by means of periodic re-photography, which is required in order to record the changes which take place in the forest as caused on the one hand by logging, fires and other depleting agencies and on the other hand by regeneration and growth. It was decided that forest re-photography was not bound by the restrictions imposed by base mapping requirements and could be taken more economically without adversely affecting the forestry value of the photograph. Low angle obliques were accordingly taken in the winter in the re-photography of the Riding Mountain National Park. The cost was one-third that of comparable verticals and at the same time very good forest information was provided.

A fertile field of investigation lies in the use of air photographs for the classification of forest sites. It has been found that, in Canadian conditions, the land form as viewed by means of the stereoscope becomes an important guide to site classification if coupled with geological knowledge and the use of the trees themselves in certain cases as site indices, along with a key to the local conditions, especially in regard to the soil, as obtained by gound work.

Considerable time has been spent on the investigation of various films and filters in regard to winter photography and for the identification of species.

The snow covered winter landscape presents pronounced contrast as between the snow and the dark evergreens and is thus a difficult subject for photography. At present the same technique of air photography is

used in the summer, when stress must be laid on accentuating the contrasts, as in the winter when the contrasts are extreme. However, it has been shown by experimental air photography over the Petawawa Forest Experiment Station that by careful photography under favourable conditions it is possible to obtain winter photographs that provide very good definition as far as the forests are concerned, assuming, of course, that the processing is carried out in a suitable manner. On the other hand it is very questionable whether both the forests and the topographical features can be shown clearly in the present technique of winter photography. In any case the snow covers much topographical detail that is visible in the summer, though at the same time, the absence of deciduous foliage permits a better view. Fortunately it is becoming practicable in many cases to have two photographic operations, one for base mapping and one for forest survey purposes. The demand for forest re-photography is conducive to the carrying out of two separate operations. In winter photography in the past it has been found that the exposure has been selected largely in reference to the snow-covered areas and consequently the dark evergreens have been under-exposed. It is, of course, necessary to make sure that the exposure is adequate for the successful photography of the dark evergreens. It is possible that a film of less contrast could be used more successfully in winter work than the present panchromatic air film. Limited experiments with infra red indicate that the brightness of the snow is ameliorated and at the same time the foliage of the evergreens is lightened. If the darkness of its shadows could be lessened, infra red might have a use in winter photography.

Infra red photography distinguishes hardwoods from softwoods in midsummer photographs, the former having generally a distinctly lighter tone. However, it is not necessary to rely on infra red for this purpose, as better results may be obtained by photographing with the ordinary panchromatic at other seasons of the year, thus taking advantage of the absence of the obscuring deciduous foliage. An investigation is being made of the distinct tones that are produced among the softwoods by infra red photography. It has been found that these tones are caused mainly by the degree of shadow between and within the crowns. In infra red photography the shadows are usually dark. On the other hand the foliage is greatly lightened because of the pronounced effect of the chlorophyll of the green foliage on the infra red film. The result is a great variety of tones ranging from black shadows to white foliage. As these tones are not necessarily caused by species characteristics, it is not yet known whether softwood species can be identified to advantage by means of infra red.

Two instruments have been originated, namely, the duoscope and the monoscope, for the transfer of detail from the photograph to the map and are being employed successfully. Also work has been done on a photo-electric planimeter which measures map areas by the aid of photo-electric cells and an ammeter.

Forest maps have been prepared for a total of 100,000 square miles, 20,000 square miles of which have been accompanied by volumetric estimating. In the balance, much of which was done before volumetric estimating was developed, the forest has merely been divided into the more obvious classes.

The Maritime Provinces have been completely photographed from the air. Nova Scotia and Prince Edward Island differ from all other Canadian provinces in regard to the ownership of their forest lands, which have been largely alienated, while in other provinces the forest lands are still held, for the most part, by the Crown. Accordingly the use of air photographs for administrative purposes is quite different in these two provinces. Nevertheless they have been very anxious to obtain forest maps from air photographs, and have entered into arrangements by which large proportions of their territories have been forest mapped by the Dominion Forest Service. Nova Scotia has been using air photographs intensively on the forests of its limited Crown lands and also for general forestry purposes throughout the province. The New Brunswick authorities have become greatly interested in air photographs, particularly in their application to forestry, and have participated in the costs of the photography that has been carried on by the Royal Canadian Air Force. A photogrammetric division has been set up and a programme of mapping is being proceeded with.

The Province of Quebec has carried on extensive air photography in the past in addition to that taken by the Royal Canadian Air Force for general mapping purposes. Also private timber holding companies have photographed considerable areas. The interest in air photography among provincial and company foresters in the Province of Quebec was to a great extent responsible for the founding of the Canadian Society of Photogrammetry.

The Province of Ontario has embarked on a five-year programme of photography of its forest lands. Old photographs taken by the Province or the Dominion are being ignored as unsuitable or out-of-date. By the aid of field work, forest maps of comparatively large scale will be made and used by the Province for forest management purposes.

The Prairie Provinces of Manitoba, Saskatchewan and Alberta have not as yet carried on air photography for forestry purposes to any great extent but have made considerable use of the air photographs that have been taken for general mapping purposes by the Royal Canadian Air Force. Many forest maps have been made, in some cases from winter photographs. The Dominion Forest Service has co-operated in the forest mapping from air photographs of several large areas in these provinces, where interest has been particularly keen in regard to volumetric estimating.

In the forests of British Columbia there are special conditions in relation to species, climate and topography which are not found elsewhere and it is to be expected that the use of air photographs for forestry purposes will have a correspondingly special development. British Columbia has carried on its own air photography along with the Royal Canadian Air Force photography, and has done considerable research in the application of stereoscopic parallax measurements to the determination of tree heights and also in the use of various films and filters for special forestry purposes, along with various photogrammetric studies.

MAPPING IN AUSTRALIA

By Colonel L. FITZGERALD
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THE mapping of Australia has now entered upon a new phase, the tempo of which must be influenced by the urgency for reconstruction and by due recognition of the still potentially tragic deficiencies of mapping of this continent.

The only regular series of topographical maps produced in Australia to date are those of the Army Survey Corps. Prior to 1939, these consisted of the 1 mile to 1 inch series covering narrow zones about the capital cities of the States, and also a few special sheets at 1 to 25,000 scale. Considering that the average strength of the Survey Corps from 1920 to 1939 was less than 20 all ranks, the amount of mapping produced was a very creditable effort.

With the outbreak of war, the then strength of 50 was rapidly augmented and eventually reached a peak of about 1,800 enlisted personnel. In addition an emergency mapping scheme under the direction of the Army Survey Service was introduced involving civil survey departments.

The bulk of this force was previously untrained in specialized topographical mapping, and in 1943 was still far below the desired effective standard, and the productions at that stage were mainly emergency editions without contours. A new series of 4 miles to 1 inch was introduced and was rapidly compiled from all available sources mostly unreliable. Other activities included the production of an 8 mile to 1 inch series covering the sparsely developed zones, in lieu of the 4 mile series, and also the Australian Aeronautical Series, at a scale of about 1 to 1 million. This latter series eventually extended over SWPA and part of SEAC. It was a joint production by civil and service agencies.

With the defeat of the Japanese Forces in the Buna, Wau, Lae, Finschaffen campaigns, the 'emergency' mapping of the mainland lapsed, and the Survey Corps concentrated its full efforts on the operational theatres, culminating in the mapping of Borneo.

On general demobilization, the Survey Corps declined to a present strength of about 500, and interim reorganization is now proceeding with a view to putting the force again into effective production.

The Organization for National Mapping has made marked progress following meetings of the Commonwealth Survey Committee and the National Mapping Council in 1945 and since.

The Commonwealth Survey Committee was originally formed in 1935, its function being to take such steps as were thought necessary to bring about the co-ordination of survey work within Australia. Its present members are representatives of the services, civil aviation, Department of

Post-War Reconstruction, and the Chairman is the Commonwealth Surveyor General. Its work prior to 1939 was not effective and it lapsed during the war until revived in 1944.

The National Mapping Council was formed in 1945 to co-ordinate the activities of the Federal and State Survey Departments. Its members consist of the Commonwealth Surveyor General (Chairman), the army member (representing the Commonwealth Survey Committee), and the Surveyors General of the six states. These advisory bodies meet half yearly.

Their primary function is to co-ordinate activities and to prevent duplication of effort.

This implies the determination of priorities and also the standardization of specifications and technique, with regard to both surveys and air photography. Only such projects as are considered of national interest, are rightly discussed, and others of a purely state domestic aspect such as normal cadastral or engineering surveys, are left to the internal organization concerned.

In this respect, it is interesting to note that the basic maps of Australia have been defined as the 1 mile and 4 mile to 1 inch series, and the responsibility for their production remains primarily with the Army Survey Corps.

The production of the Aeronautical Series is now in abeyance pending clarification between Department of Air and Department of Civil Aviation concerning types to be used in future.

The Royal Australian Air Force has maintained a Survey Flight for many years and it is now at its peak of effectiveness. It is responsible for air photography for the service sand on behalf of the Commonwealth Survey Committee.

The rights of private enterprise in this respect are recognized, and the RAAF activities are usually restricted to medium and small scale photography suitable for basic mapping, and large scale photography is normally left to the commercial aircraft operating companies.

Hydrographic survey is the function of the Navy and the hydrographic branch RAN is actively engaged on a post-war programme.

With regard to the geodetic survey of Australia, the Army Survey Corps will continue its activities in this respect. The nomination of the responsible agency for this work is under consideration by the National Mapping Council and a decision at the next meeting is expected.

In view of the huge area of Australia still unco-ordinated by triangulation, the development of the application of radar to surveying is of considerable interest and the early acquisition of equipment is expected. The results achieved to date are sufficiently conclusive to ensure that it could be applied effectively to mapping at 1 and 4 miles to 1 inch ; and in the mandated territories, the terrain and communications are so adverse that it is considered that radar is the only effective and economical answer to the problem of obtaining survey control for mapping.

With regard to photogrammetic equipment, the supply situation during the war prevented the acquisition of other than simple types. The Army Survey Corps is now endeavouring to procure multiplex equipment from United Kingdom sources.

Even with the revolutionary advances in mapping technique developed

over the war years, the size of the Australian Continent is so great, that planning must still be based on a long-term period.

There are such vast areas still unknown, that the production of 4 mile sheets must to a great extent be given priority over the routine mapping at 1 mile to 1 inch. It is obvious, however, that the nation is now map conscious and one can hopefully visualize a mapped country in the course of a generation or two, rather than over a period of centuries as was previously conceived.

MODERN MAPPING—INCLUDING THE EMPLOYMENT OF RADIO TECHNIQUES AND WITH SPECIAL REFERENCE TO ECONOMIC DEVELOPMENT

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1. INTRODUCTION

Recently it has become apparent that modern surveys will be increasingly influenced by the availability of additional data arising from the employment of radio techniques.

This has two aspects :

(*a*) The employment of radar pulse measurements of distance to provide absolute fixation, in relation to remote radar stations, of an aircraft at the instant of exposure of an air photograph. By this means scale can be established and, if necessary (e.g. under operational conditions) suitable contoured tactical maps can be made, up to a scale of 1/25,000 without any access to the ground in the area being mapped. Even if some ground control is available, the survey work is greatly facilitated.

The main incentive for development of radar control methods for air survey arose from the complete lack of ground data and adequate maps in Far Eastern areas under enemy occupation. The basis of this aspect has been discussed elsewhere.*

(*b*) The extension of triangulations over wide gaps for which two methods are available.

Firstly, the length of a long line between radar ground stations which are not inter-visible can be measured by flying an aircraft across the base-line, as a development of a method first employed for calibration flights in connexion with radar fixations of air photographs. Under certain conditions, lines up to 500 miles or more may be measured with an accuracy at present estimated to be within one part in 20,000 to 30,000.

Secondly, the parachute flare method, which also employs radar navigation and synchronized radio signals (to enable simultaneous theodolite observations to be made on the flares from a number of stations), is considered to be effective up to 400 miles. This method arose quite independently before the full possibilities of radar measurement had been explored.

In this paper experimental work which has been undertaken is described and analysed and the effect of availability of the new methods upon economic developments is discussed.

2. EXPERIMENTAL SURVEYS INCORPORATING NEW METHODS

These fall under three headings :

(i) Application of radar to air survey, War Office 1943 onwards.

(ii) Ranging of long lines between radar stations in the Mediterranean, April–May 1945.

(iii) Triangulation connexion between Denmark and Norway by parachute flare method, July–August 1945.

* Hart, C. A. 1946. *Surveying from air photographs by remote radar control.* R. Soc. Emp. Sci. Con.

2. (1) Experimental work on the application of radar to air survey, undertaken at the instance of the Directorate of Military Survey, War Office

During the late war, operations were much hampered not only by the lack of maps at tactical scales in South East Asia, but also by the complete absence of ground control in many areas. This ground control, even if existent and available to us, was not identifiable on air photographs.

In the middle of 1943, the author initiated the first experiments in the employment of radar as an aid to air survey, and these were carried out in co-operation with the Air Ministry and Ministry of Aircraft Production. The device used was ' Gee-H,' and the technique crude, since the survey trials were subsidiary to bombing trials. Nevertheless, the result was successful in that the position of the aircraft was established to within 70–100 metres. After a visit to South East Asia, where the Supreme Commander pressed for the development in the United Kingdom of radar aids for mapping without ground control, the author returned to the War Office to carry out an intensive experimental programme at the Directorate of Military Survey.

After analysis of the preliminary flights with ' Gee-H,' it was decided that ' Oboe,' with its much greater intrinsic accuracy, should be tried, and in August 1944 a survey block was flown in the vicinity of Royston using ' Oboe ' Mk. I installed in a Fortress aircraft, having an automatic pilot and controlled by stations 85 miles away. In this system the aircraft is flown on a circular arc of which the ground station (or ' cat ') is the centre. Pulses transmitted from this station to the aircraft provide equi-range indication to the pilot by means of an aural signal, while re-transmission from the aircraft to the ground station allows of automatic recording of actual track variation there. For the experimental flight the camera was operated by remote control at predetermined release points from the second or ' mouse ' ground station. Altimeter records of a Kollsman type of altimeter were photographed by a slave camera synchronized with the survey camera. This block of photography proved invaluable for testing the methods which were devised for control computation * and for assessing the value of new methods of compilation which were tried out. Some of these are referred to later.

The problems of co-ordination and working under operational conditions in South East Asia made it necessary to select for the purpose a light mobile ' Gee-H ' system, which, although its intrinsic accuracy was about half that of ' Oboe,' could be put into operation

(*a*) quickly
(*b*) under tropical operational conditions
(*c*) with maximum mobility of stations, and
(*d*) with minimum liaison between ground stations and aircraft, since in this system the main pulse transmitter is in the aircraft, the two ground stations acting as beacons which return pulse signals to the aircraft so that the ranges may be measured.

Several experimental blocks were flown with a modified ' Gee-H ' installation fitted in a P.R. Mosquito aircraft, operating with special light

* Hart, C. A. 1946. *Surveying from air photographs by remote radar control.* R. Soc. Emp. Sci. Con.

transportable ground stations. At predetermined positions the navigator operated the survey camera, which in turn 'triggered' the automatic observer * where range measurement and other data were recorded. A suitable technique was devised for 1/50,000 plans up to 200, and possibly 250, miles from the ground stations. Errors of altimetry in this type of aircraft, however, gave rise to appreciable heighting errors.

Finally as a result of the experimental work a special R.A.F. Radar-controlled Air Survey Unit was formed, to work in conjunction with a Radar Survey Section R.E. consisting of carefully selected personnel from the experimental team. This unit was destined for South East Asia, but owing to the termination of the war, its efforts were diverted elsewhere for radar-aided air survey under peace-time conditions.

Throughout the investigations Air Staff policy was guided by the Air Survey Development Committee (Chairman, G/Capt. F. C. V. Laws, C.B., C.B.E., the author acting as Secretary).

As regards the experimental work under the aegis of the War Office, the author acknowledges the practical help and guidance given him by his chief, Brigadier M. Hotine, C.B.E., Director of Military Survey, at the time.

He could not let this opportunity pass of acknowledging with grateful thanks the whole-hearted co-operation received from the Air Ministry, Ministry of Aircraft Production, Telecommunications Research Establishment, Air Warfare Analysis Section and the Royal Aircraft Establishment, as regards installations and flying, while the enthusiastic technical support received from Survey Units R.E., Royal Canadian Engineers, U.S. Corps of Engineers and Royal Marines alike, enabled the survey analyses to be successfully concluded.

2. (2) Mediterranean experiments in the ranging of long lines

During the latter stages of the war in Italy an R.E. survey team was engaged in computing radar fixed bombing targets for the U.S. Army Air Force. At the conclusion of this work, arrangements were made at the instance of Brigadier R. Ll. Brown, C.B.E., Director of Survey Allied Force H.Q., for Captain D. J. Halliday, M.B.E., R.E., to carry out a series of experimental measurements of long lines between radar stations, by flying an aircraft equipped with radar across the base-line several times. Results giving accuracy significant for geodetic survey were obtained.

2. (3) Connexion of Denmark and Norway by the parachute flare method

The method of connecting triangulations over a wide gap by simultaneous theodolite readings from three stations on each side on to parachute flares dropped from aircraft in pre-determined positions was devised by Lt. Colonel W. E. Browne, O.B.E., R.E. This was originally planned for making a connexion between the south coast of England and France, in the neighbourhood of the Normandy beaches, shortly after D day, but it proved impossible to try it at that time. An opportunity offered itself, however, after the conclusion of hostilities in Europe for him to put it into effect.

* Hart, C. A. 1946. *Surveying from air photographs by remote radar control.* R. Soc. Emp. Sci. Con.

Close co-operation from the R.A.F. and U.S. Engineers, as well as the Danes and Norwegians, enabled sufficient results to be obtained for the connexion over the 90-mile gap of the Skagerrak to establish the suitability of the method for extending and connecting major triangulations.

3. PREPARATION OF MAPS SOLELY FROM RADAR-CONTROLLED PHOTOGRAPHY

3. (1) Introduction

During the early stages of experimental work considerable effort was expended in testing various methods of relating the camera fix to the ground. It was natural that complete tilt analysis should have been tried first to give the best assessment of radar accuracy, but the heavy labour of such tilt determination from stereocomparator readings made it necessary to seek more practicable methods.

Several experimental blocks of photographs have been flown and various survey experiments carried out, firstly for the preparation of hurried operational plans without any tilt analysis at all, and secondly for mapping both in plan and contour with minimum tilt analysis. Brief descriptions of methods used follow.

3. (2) Map compiled from complete tilt analysis

An experimental contoured map was made for the central portion of the 'Oboe block,' consisting of four strips each of seven photographs, overlaps being 60 per cent both longitudinally and laterally.

Relative tilts were determined from stereocomparator readings and computation.* Then, using radar-fixed grid co-ordinates of the plumb-points (known to be relatively accurate to ± 20–25 metres), and altimeter differences accurate to ± 5 metres or less, control points for plan and height were computed along the strips by the 'three corner' method. Slotted templates were used for the preparation of the plan by radial-line method while height control was extended by parallax bar measurements and contours were plotted by stereoscopic interpolation. The compilation was carried out by a survey unit without knowledge of the location of the area.

The compilation was made at mean photo-scale (1/17,500) from the control supplied. Plan and contour plates were then fair-drawn at the appropriate scale for reduction (*a*) to 1/25,000 and (*b*) to 1 inch to 1 mile.

Fig. 1† shows a comparison of the radar-controlled plan (in red) with the corresponding portion of the G.S.G.S. 3906 1/25,000 map of the Royston area. The comparison is made by 'best mean fit' of detail, the grid shift arising from a systematic error of $+77$ metres E. and -5 metres N., due to lack of appreciation in the early tests of the necessity for survey range calibration. The effect is even more striking when the one-inch maps are compared.

* Hart, C. A. 1946. *Surveying from air photographs by remote radar control.* R. Soc. Emp. Sci. Con.

† All figures referred to in this paper will be found at the end of the paper, *i.e.*, facing page 646.

A comparison of the contour plates is not given here, but two comparative sections have been drawn (see fig. 2).

Internal agreement of points of detail is to within about ±20 metres, and the relative heights are accurate to about ±10 metres,* the topographical shapes, as depicted by the contours, agreeing very well.

The time taken to compute control by the method employed is quite excessive—for this small area some 60–70 man-days were required—although considerable reduction would be achieved if the relative tilts were determined in a three-dimensional instrument.

3. (3) Compilation of plan without tilt analysis

Parallel with the above experiments others were undertaken in order to test the accuracy obtainable with no tilt analysis at all, since success would allow of rapid production under urgent operational conditions of controlled tactical plans or photo-maps.

Each radar-fixed plumb-point was assumed to be coincident with the corresponding principal point, so that random errors arose from tilt as well as radar fix. Self-consistency was achieved by fitting the block as a whole (usually by slotted template) to the radar fixes, and accepting a position of ' best mean fit ' for the block or group of points.

As a test of the accuracy obtainable, a slotted template assembly was made at a scale of 1/30,000 of a block of 165 ' Gee-H ' controlled photographs taken in the Norwich area at approximately the same scale. Five groups each of five fixes were used as control, one centrally and the remainder in the corners of the block ; the slotted templates for each group being assembled by eye to ' best mean fit ' before assembling the block as a whole.

For a representative group the mean Easting was —17·4 metres and the mean Northing +6 metres ; and from the values thus obtained adjusted co-ordinates were computed. One principal point was then selected from each group as a control point, and its ' best mean fit ' position plotted on a master grid and the slotted template assembly completed. Comparison with the Ordnance Survey map showed systematic errors of +19 metres E. and +24 metres N., leaving residual random errors between —41 and +94 metres E., and between —94 and +97 metres N.

One hundred and sixty-five points of detail over the block were intersected on the master grid from principal points positioned on the assembled templates, and their errors in relation to the O.S. map gave systematic errors of +59 metres E. and +29 metres N., leaving probable random errors of about ±30 metres E. and ±50 metres N.

Another experiment for a block of 70 photographs (also flown with ' Gee-H ') in the Cader Idris area, where the ground height variation was greater, gave similar results.

The experiments have established that such averaging of a proportion of fixes arranged in a suitable pattern will reduce random photographic errors throughout to less than that of the radar system.

* It should be noted that the contours on the 1/25,000 map have been determined instrumentally at intervals of 50 ft. vertical interval, the remainder being interpolated, so that the map values themselves are not likely to be very accurate.

3. (4) Compilation of plan with limited tilt analysis

As experiments proceeded, it became evident that the most practicable methods consisted of accurate computation of absolute tilts in selected positions, with some means of connecting these observations together for complete determination.

An experiment was made with the same block of 165 photographs controlled by the same fixes for fixating the same detail points. Absolute tilts were computed by the ' three-corner ' method, thus eliminating tilt errors as far as the altimetry would allow. The systematic errors over the block were consistent and similar to those found without tilt analysis, but the random probable errors of the detail points were cut by about 50 per cent, being ±15 metres E. and ±20 metres N. Since ' Gee-H ' ranges appear to be subject to random errors of at least ±50 metres, this result is remarkable.

Another slotted template experiment was made for the ' Oboe ' block of 52 photographs, where the ' three-corner ' control in each corner was connected by principal point traversing. The systematic errors of the principal points were +5 metres E. and −63 metres N. due to lack of calibration as mentioned above, while the random errors were approximately ±10 metres for both E. and N.

A third experiment was made with a block of ' Gee-H ' controlled photographs of Anglesey at a scale of 1/52,500, with a view to developing a simple and accurate plan technique for work in the Far East. Plan control was derived from two diagonally opposite ' three-corner ' absolute tilt determinations which were connected by a closed principal point traverse, the total number of man-hours required for producing control being only 39. A small systematic error (of 30–40 metres) was again due to a residual calibration error which was later almost eradicated for this type of equipment. The random error compared with the O.S. one-inch map was about ±50 metres both E. and N.

3. (5) Heighting with partial tilt analysis

The accuracy of determination of relative ground height is dependent on the accuracy of the altimeter differences. Some experimental work photogrammetric determinations of aircraft heights were made during the course of the trials in order to check altimeter values, but more investigation is required.

Altimeter differences for the ' Oboe ' test flown with a Fortress aircraft were correct to ±5 metres or so, deduced relative ground heights being correct to ±10 metres or less. For ' Gee-H ' tests the liveliness of the Mosquito gave rise to random errors found after considerable investigation to be as much as ±30–40 metres. In view of the urgent requirement for radar survey in the Far East at that time, it was decided to concentrate on plan work with ' Gee-H,' for which the accuracies were adequate.

Satisfactory results for bridging height control have been obtained by multiplex, during experiments carried out by the U.S. Engineers and the Royal Canadian Engineers at the instance of the Directorate of Military Survey.

The Canadian experiments were largely directed to developing a technique but results are not yet conclusive without tilt analysis of maximum

accuracy. The American experiments were designed to test the efficacy of bridging between ' three-corner ' control, connected by principal point traversing. By utilizing this control at intervals of every six overlaps, bridged for scale and azimuth by means of rectified slotted templates as projected by multiplex, and for height by systematically distributed corrections along the strip, the values obtained for test points along the strip were of the same order of accuracy as the control which was supplied. The tests were made with strips each of seven photographs of the ' Oboe ' block with five or six computed control points in each terminal overlap. Photogrammetric control was supplied by the Directorate and the tests consisted of determining the co-ordinates and heights of a number of intermediate test points. Upon receipt of the values as determined by multiplex, these were compared with the true ground values, and an example of the results obtained for one strip is given in fig. 3. It will be noticed that in this instance the accuracy of the intermediate points after they had been brought into harmony during the bridging process, was in general rather greater than that of the control originally supplied and which itself had been somewhat improved in the process.

Results of a similar order were obtained from the Canadian experiments without computed control for the flat country of Anglesey, but these tests have not yet been extended to more hilly areas.

4. GEODETIC CONNEXIONS OVER WIDE GAPS

4. (1) Radar ranging

(*a*) *Ground-to-ground measurement*—The distance between two ground stations can be measured directly by radar, but range is limited to the optical horizon which can rarely be expected to exceed 100 kilometres. The fundamental accuracy at present obtainable with radar is about ±20 metres so that the limiting accuracy of a single measurement at this range is 1/5,000. The main disadvantage of ground-to-ground measurement is that it is near the ground that abnormal atmospheric conditions, not yet fully understood, most frequently occur and even if observations are taken under stable conditions, it will be a long time before it can be hoped to provide results comparable with those obtainable by normal geodetic triangulation.

An experiment was carried out in Italy in 1945 over a distance of 66 miles, and the mean of several independent readings taken on the same day agreed to 1 metre with the computed distance, but this result is considered fortuitous.

(*b*) *Flying across the base*—A method which offers far more promise is that of flying an aircraft several times across the base between two ground stations, the mean of the ' minimum sum ' of the radar ranges obtained from each flight enabling the geodetic distance to be obtained, after calibration of the radar apparatus. Range obtainable is dependent upon aircraft and ground station altitudes. In Italy, during experimental flights, a base 618 kilometres long was measured from a mean of 22 flights, using an aircraft flying at between 11,000 and 15,000 feet the estimated accuracy after investigation of propagation conditions approaching 1 in

30,000. The great length of the base introduced problems in the computation of long lines. By flying at 30,000 feet the distance might have been extended to 800 kilometres or more.

Another experiment was made over a length of 126 miles. The mean distance from separate flights on the same day gave a fortuitous accuracy of 2 metres compared with the geodetic distance.

Further work is now in hand in the Caribbean, but it is considered that more knowledge of the laws of variations of velocity of propagation is required before a universal accuracy greater than about 1 part in 15,000 to 20,000 can be guaranteed.

4. (2) THE PARACHUTE FLARE METHOD—DENMARK–NORWAY CONNEXION

Although Denmark and Sweden are closely linked by modern first-order triangulation the connexion between Denmark and Norway was selected for the test because it depended upon one point of which the identity is not certain. The task was carried out in a limited time between mid-July and early August 1945.

The method, simple in conception, needed elaborate co-ordination of effort, and is illustrated by reference to fig. 4 showing the arrangement of stations for the connexion. Three primary stations were occupied on each side of the Skagerrak and a series of observations of primary standard, taken simultaneously from all of them at points A, B and C on to parachute flares dropped from aircraft flying along the great circle route connecting them. The assumption made is that, given a sufficient number of suitable observations, computation from each side gives the change of origin, and scale change and azimuth swing between the two systems ; so that the connexion can be established from either side.

Two theodolites were set up for observing at each triangulation station, one or both being at satellites. The Norwegian stations were all on mountains, but two towers were built at the Danish stations, one for each instrument. Originally it was planned to observe 64 arcs from each station, assuming that only two shots could be obtained per flare. It was found, however, that four shots could be obtained per flare, and the arcs were reduced to 32. Unfortunately break-up of the R.A.F. Wellington squadron did not allow of completion.

Radar was employed for the navigation of the aircraft, the Jutland Gee chain being used, Gee fixes of A, B and C on a great circle route being computed, the specification being that flares must be dropped within ±2 miles of the computed positions.

Direct radio speech communication with the aircraft was maintained by an R.A.F. set in the same van as a broadcasting station at Lerup, so that a signal could be broadcast immediately it was received from the aircraft, and received in earphones by the various theodolite observers.

The aircraft normally flew at night at an altitude of 8,000 feet, dropping yellow parachute flares igniting at about 7,000 feet, the angle of inclination avoiding the necessity of striding levels at stations. One minute before reaching a station (say, station A), the navigator would signal a warning and a series of A's was broadcast and picked up by the observers. On dropping the flare, the navigator would signal again and a series of X's was broadcast. At 2, 3 and 4 minutes a time signal was broadcast, and at the

last ' dot ' all observations from the ground stations were simultaneously made to the flare. Some 10 minutes was available before observations to station B.

Naturally difficulties arose, in particular cumulo-stratus clouds sometimes necessitated adjustment of flying height, and, owing to failure of the Gee chain on some occasions, position and course was more accurately achieved by simultaneous sighting on flares, reporting bearings to aircraft control stations, plotting for course and position and informing aircraft, than by dead reckoning.

After practice it was found that the maximum discrepancy of angle comparisons at a station was not greater than 7″, arising largely from the personal factor of the observers. The maximum rate of travel of a flare was 25 m./sec., or about 63″, so that 7″ represented 0·1 second of time.

Preliminary computation to each of the sea points A, B and C indicate that the value of one fix (i.e., one shot on one flare from all stations) is correct to about ±5 metres. Geographical co-ordinates of both Norwegian and Danish land stations were converted to rectangular co-ordinates on the North European Zone III Grid, and then the rectangulars of the series of flares at A, B and C were computed from both sides. The discrepancy of orgins appears to be approximately 154 metres E. and 172 metres N. (Norwegian-Danish), and if there are no scale and rotation errors between the systems, then the differences will be constant at A, B and C.

Both Norwegian and Danish Institutes intend to compute the connexion as an extension of their own networks.

4. (3) Modification of geodetic technique arising from the possibility of accurate measurement of long lines

The measurement of long lines to a high degree of accuracy by means of radar opens up attractive possibilities in geodetic work. A network of triangles may be computed equally well from observed lengths of sides as from observed angles, with equal scope for ' least square ' adjustment in the case of fully observed polygons.

ABCD in fig. 5 is a regular figure with side (a) and diagonal (d), in which the co-ordinates of A and B are known. Let the standard error of a single measurement be σ, independent of distance, and suppose each side and diagonal to be measured n times. Then the total number of measurements is $6n$, of which four only would be sufficient to determine the positions of C and D relative to A and B. The standard error of each individual side after least square adjustment is therefore about :—

$$\sigma \sqrt{\frac{4}{6n}}$$

Assuming a plane figure, the accuracy of fixation of C and D is then :—

$$\sigma \sqrt{\frac{4}{6n}} \cdot \frac{\sqrt{2}}{\sin \mathrm{ACB}}$$

For a spherical figure, the accuracy of fixation is not significantly different.

5. ECONOMIC EFFECT OF IMPROVEMENTS IN SURVEY TECHNIQUE

5. (1) EXPEDITIOUS AND ACCURATE AIR PHOTOGRAPHY AND SURVEY BY RADIO AIDS ; ECONOMIC ASPECT

Radar control for flying already enables gap-free flying in the desired positions to be achieved for photographic scales up to about 1/10,000, using a lateral overlap of 20 per cent ; for smaller scales, e.g. 1/25,000 to 1/30,000, the lateral overlap can be cut to 15 per cent or less. Without such aids, 25 to 30 per cent lateral overlap must be allowed for, and even then gap-filling sorties are frequently required.

If the accuracy of range measurement is adequate for the map scale required and the altimetry is fairly accurate, no ground control whatever is required other than that for the fixation of the remote radar ground stations. This condition can already be achieved for scales of 1/25,000 and smaller, so that in effect the only ground control which is required for mapping by remote control in these scales is of the order of a primary triangulation (i.e. points spaced at, say, 40–50 miles). In effect, of course, this means that either the trigonometrical point itself is used as a radar station, with a check provided by identifiable primary stations on the photographs in the area of the survey, or locally related and identifiable points.

For a given range accuracy of ±20 metres, the photographs being taken with a 6-inch lens from 12,500 feet, it would be desirable for 1/25,000 contouring comparable with ground standards to provide about four to six suitably spaced spot heights in a block consisting of seven strips of seven photographs flown with 60 per cent forward and lateral overlaps (i.e., in this instance, one spot height per 20–25 square miles).

The amount by which radar fixes can advantageously reduce ground control is dependent upon the type of country. The size of block suggested above is suitable for bridging in a standard wide-angle 7-projector multiplex bar. When necessary ground control can be dispensed with altogether ; the accuracy obtainable by the most accurate radar device at present available, but not yet adapted for survey, being relatively ±20 metres in plan and ±10 metres in height, given reliable differential altimetry.

The economic aspect of radar-aided air survey under commercial conditions is not yet established. It is probable, however, that provided the ground station crews can be reduced to a minimum decided by peace-time and not operational conditions in areas which are as yet undeveloped and where ground control is scanty it will pay its way at once in ensuring efficient coverage. Even if one or two strips are failures because of clouds or camera failure, etc., it is a perfectly simple matter to fly those strips subsequently exactly in position and not, as has been necessary sometimes in the past, to make several attempts before gaps are filled.

The relative economics of full radar fixation with that of control on the ground are difficult to assess, since it is not yet possible to quote any actual figures of costs in connexion with the employment of radar aids for survey purposes. It is nevertheless very important to weigh carefully the relative merits of this method whereby all the necessary data for economic study and map-making can be obtained in a few months instead of years, so

that those parts of a country which are required to be developed immediately can be mapped as part of the whole programme.

5. (2) Primary networks by ranging of long lines

The accuracy which has so far been established shows that, in cases where it has not previously been possible to determine relative positions other than by astronomical observations, the radar ranging method of flying an aircraft between stations up to 500 miles apart will give an accuracy which may be one part in 20,000 or better for lines of 100 miles or more. For shorter lines, however, further investigation is required. An example of the type of figure it is possible to range by radar is given in fig. 6.

The flare method has also been shown to be a valuable addition to geodetic technique, and Browne considers that it will be effective up to 400 miles, and it seems likely that its accuracy may be 1/30,000 or better.

For connexions over wide stretches of water, astronomical observation does not allow of a rigid framework. Although much research and development work remains to be done, these two new methods offer a means of producing an overall network embracing every national triangulation with one homogeneous whole.

There are many other connexions which have not yet been effectively achieved, such as Italy and Sicily to Tunisia (200 miles), and Turkey–Cyprus–Egypt (80 and 270 miles). Work is already planned by U.S. surveyors for the first-order connexion between Florida and S. America via the Bahamas and the Lesser Antilles, with a loop from Florida to Cuba and across to Yucatan, Jamaica and Santo Domingo being included in the scheme.

A particular advantage in these methods is that archipelagos, where the islands are widely spaced, can now be accurately connected (e.g. the Aleutians and various Pacific Ocean groups). They should be of particular value to the hydrographic surveyor, who has hitherto always been in some difficulty regarding construction of charts in such areas. It may even prove economical to achieve connexion by this means across stretches of desert country.

In addition, the hydrographic surveyor can use the radar fix (either by 'Gee-H' as described for short ranges, or possibly for longer ranges by means of a low-frequency radio 'phase-difference' navigator fitted in either aircraft or surface vessels) for accurate location of reefs, etc.

5. (3) Employment of radio navigational aids for exploratory surveys

Recourse must be made to one of the long-range navigational aids. The technique may be either low-frequency pulse, such as 'Loran,' or low-frequency radio 'phase difference,' such as the Decca. In either case three stations are employed, a master and two slaves, the fix being defined from the difference in distance (or phase) from the master and each slave. Effective range is much longer since an optical path is not necessary, and by a suitable arrangement of stations accuracy of location to half a mile or so can be achieved on sea or in the air by day for ranges up to 600–700 miles.

Thus, given a suitable ground station installation, it should be possible to map at these ranges at reconnaissance scales (say 1/250,000) from air photos fixed to this order of accuracy, which should prove of considerable value in comparatively unexplored areas such as Northern Canada.

5. (4) Advantages of speedy and accurate modern survey techniques in the acceleration of economic development

The advantages of employment of radar for locating air photographs in countries where development is urgently required, whether it be to control navigation only or to provide an additional aid to survey by fixation of photographs, are that by ensuring efficient and economical coverage with minimum delay it provides the geologist, forester, botanist, agriculturalist, engineer, etc., with material upon which to make his preliminary plans while surveyors are plotting the maps. This makes for efficiency because the surveyor is enabled ' without delay ' to adjust his order of mapping to suit the programme of development ; *and above all*, from the surveyor's aspect, the limited ground control necessary can be provided in a tenth of the time required for full control by ground methods.

The economical application of radar to survey cannot be assessed by a bald estimate of radar costs against the cost of the complete job by other methods. Not only is the time factor important, but also owing to the greater efficiency with which the flying can be carried out, giving uniform strips and matched overlaps, the task of plotting will be made much easier and cheaper. Moreover, all countries concerned in economic development will have maps available much earlier than they would ever have with normal methods and be able to make their plans much more efficiently.

5. (5) Need for research ; conclusions

It is considered that the successful application of the methods described in this paper will have an effect upon survey methods in general comparable with that of the original application of air photography, not only in air survey but also in primary triangulation. This new application of survey should play a very full part in assisting the surveyor in his work of pioneer economic development wherever it is required.

It is essential that sufficient scope and inducement be offered to those scientifically qualified to ensure that enthusiasm is maintained, and that the methods are developed and applied intelligently. Without scientific application by surveyors, with full realization that fully-trained specialists must be employed in the work from the radar, navigational, meteorological, photographic and survey angles, disappointments will arise and bring temporary discredit on these methods.

So far as topographical mapping is concerned, it is safe to say that, given stabilized photography (e.g. with a maximum tilt of 1°) in a steady-flying aircraft in which altimetric differences can be measured accurately, it is possible, by photogrammetric analysis of one kind or another, to produce 1/25,000 contoured maps of an accuracy equal to that obtained by ordinary survey methods and without any ground control other than that provided by the remote radar stations. The only proviso is that without some direct reference to the ground the absolute datum is not

yet accurately determinable. It is hoped that it will soon be possible to fly radar-controlled strips sensibly straight in any direction suitable to the topography, irrespective of the actual location of the radar ground stations. The economic balance between the photogrammetric work required when no ground control is used and that required when a limited amount of control is fixed has not yet, however, been established.

The measurement of long lines offers great promise, but much research work remains to be done in connexion with propagation, particularly in relation to day-to-day meteorological conditions.

The more stringent requirements of large-scale survey should be considered. Since single range readings are likely to be in error in the near future by as much as ± 20 metres, which is beyond the standard required for, say, 1/5,000 photography, new methods must be adopted. There is need for research work in connexion with the application of radar to large-scale survey by the employment of helicopters equipped with radar apparatus so that, while hovering, an integrated series of readings can be taken over a short interval of time, the helicopter and the camera it carries being stabilized and accurate tilt determined. It may be possible to determine the position of the air camera at the moment of exposure to the nearest 3 or 4 metres as well as its inclination to a few minutes, and, if so, then another advance in survey will have been made. Improved accuracy of altimetric measurement is also required, necessitating further experiments. This large-scale problem should, however, be treated quite independently from that of topographical surveys.

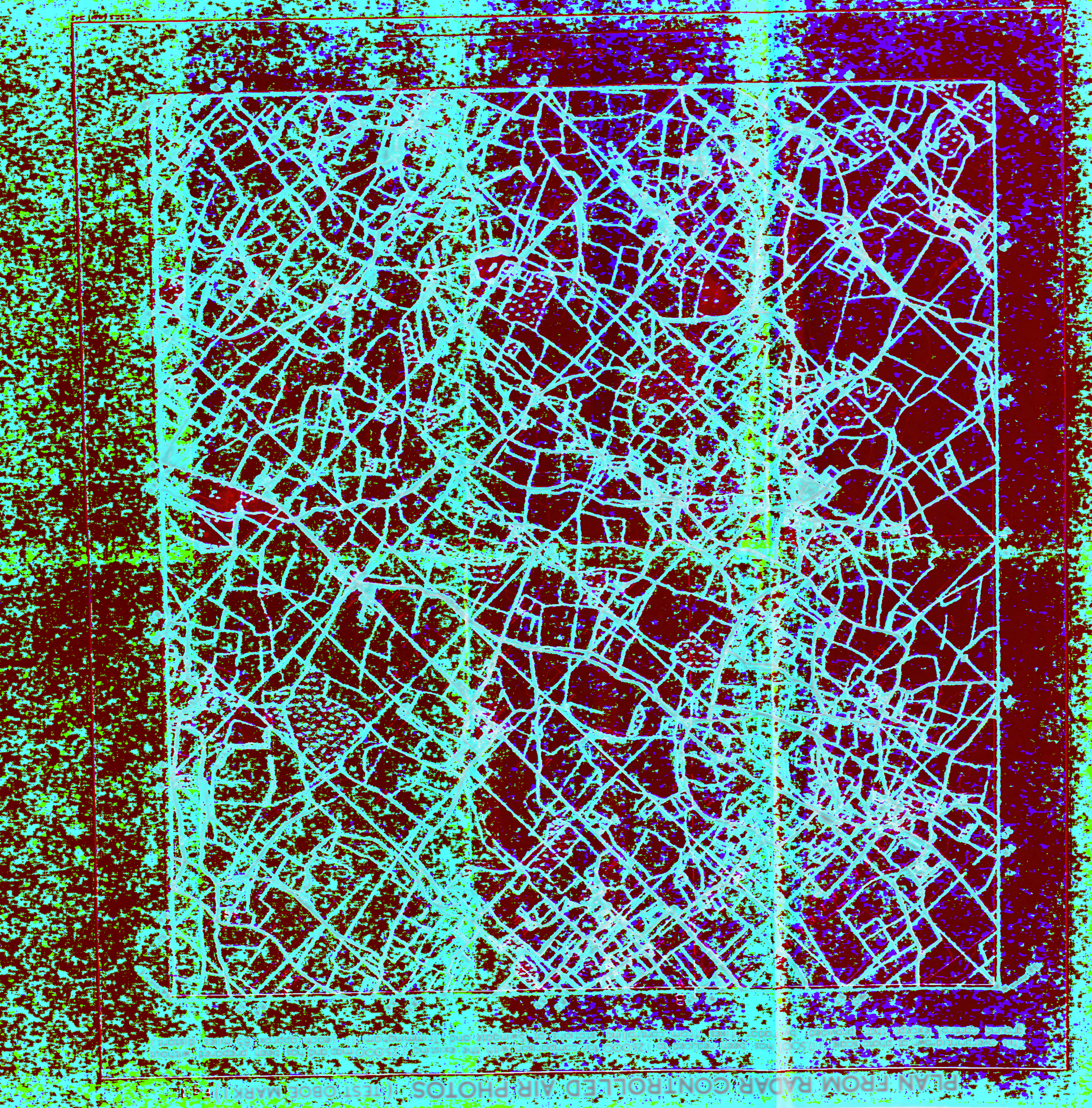
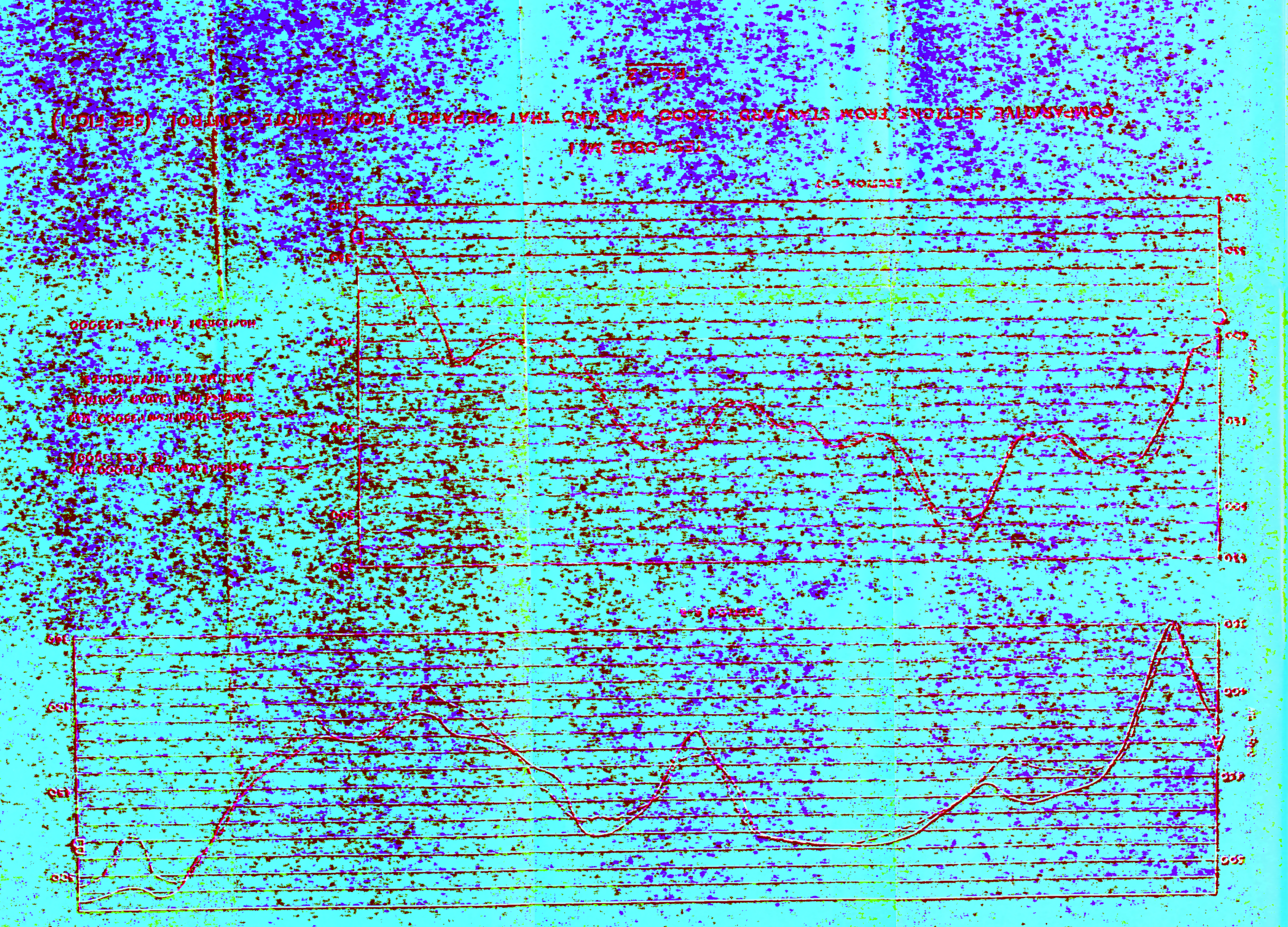
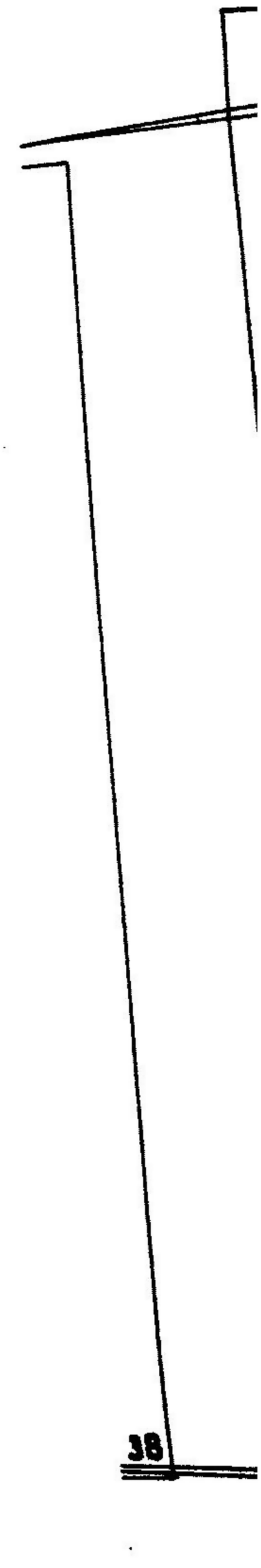

PLAN FROM RADAR CONTROLLED AIR PHOTOS

FIGURE 3

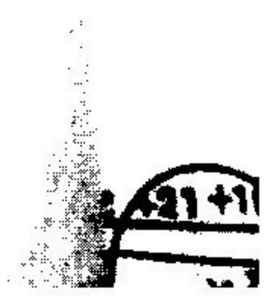
COMPARATIVE SECTIONS FROM STANDARD 1:5000 MAP AND THAT PREPARED FROM AERIAL PHOTOGRAPH. (SEE FIG 1)

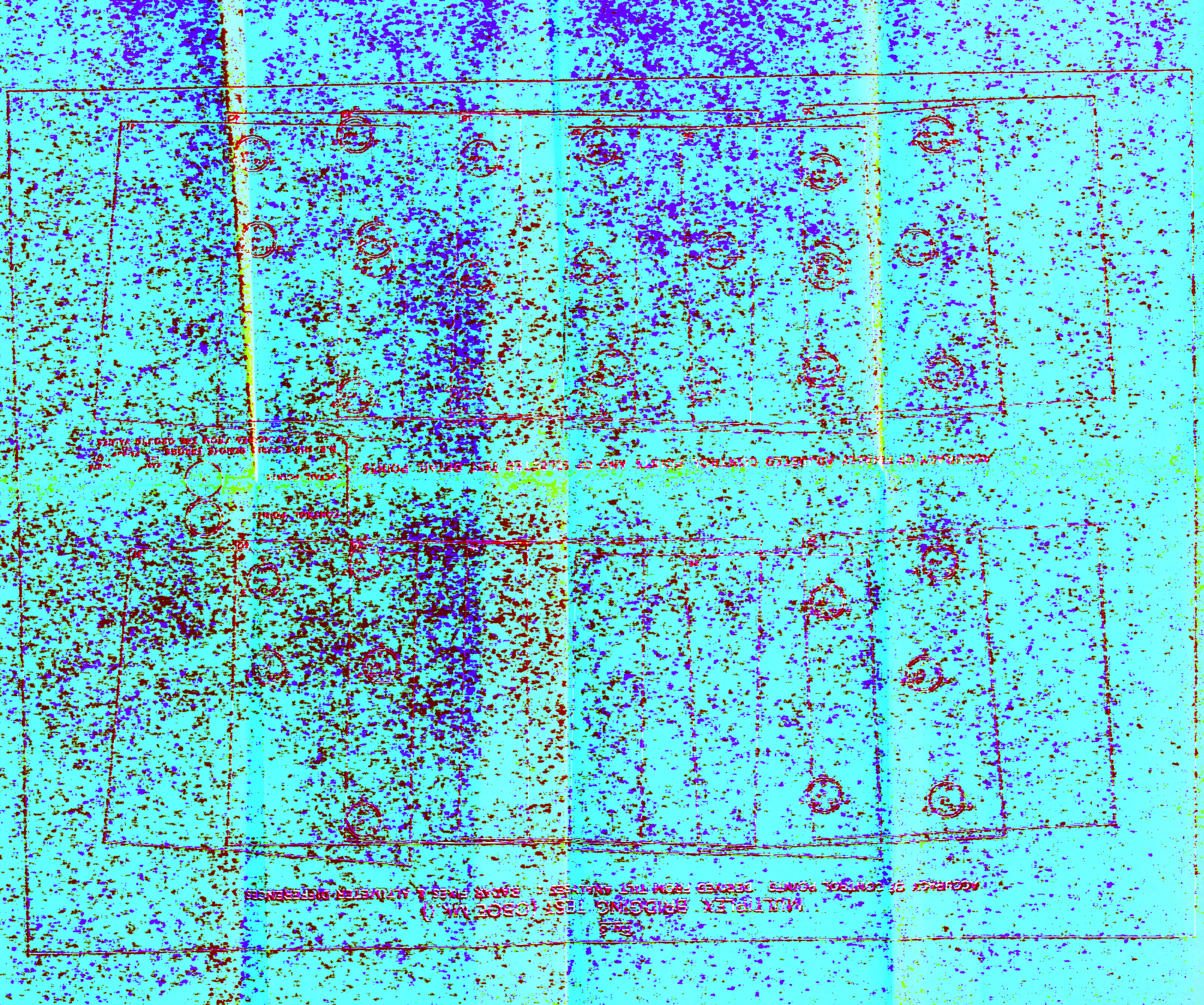


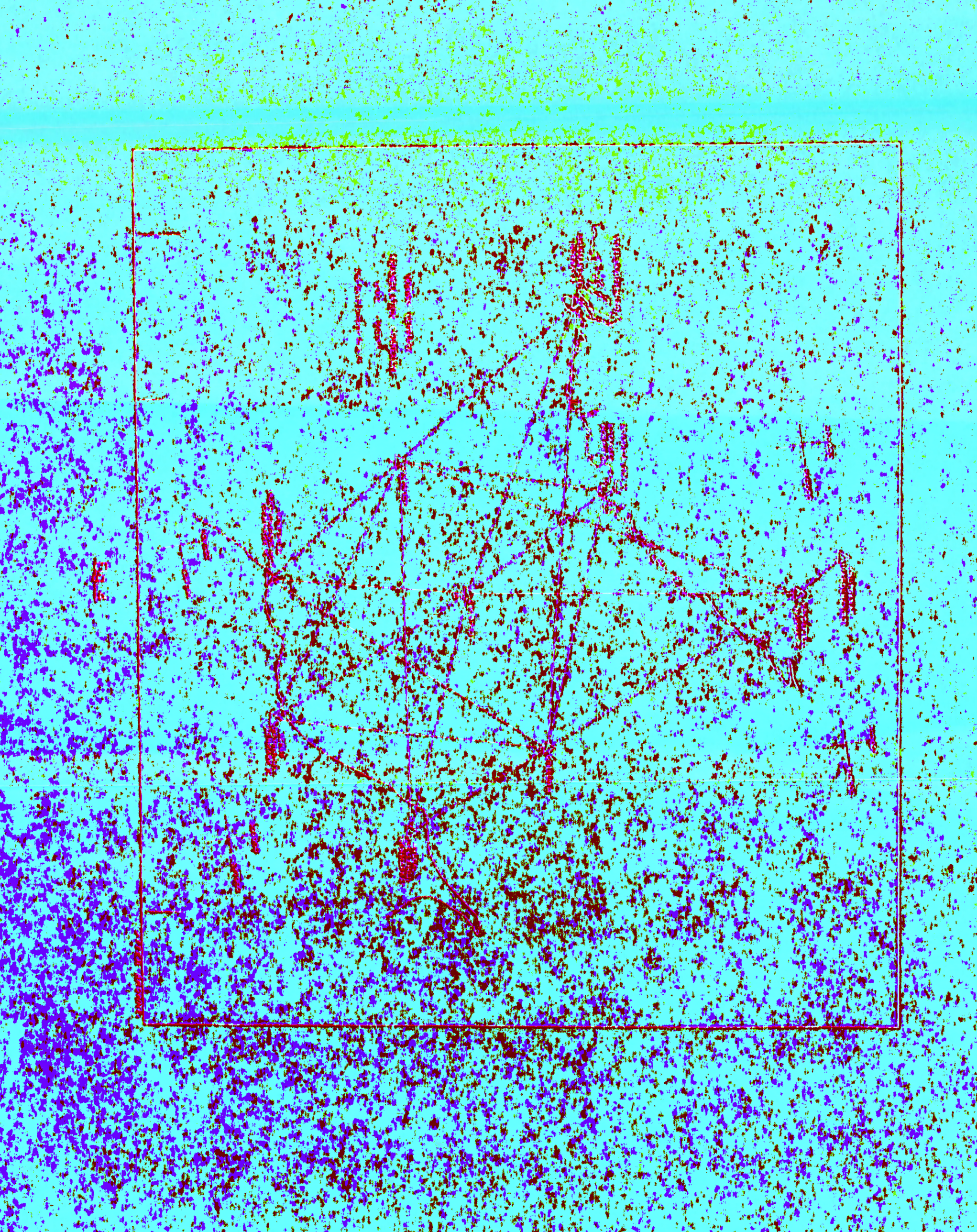
Mk.1)
FIXES & ALT



ST D

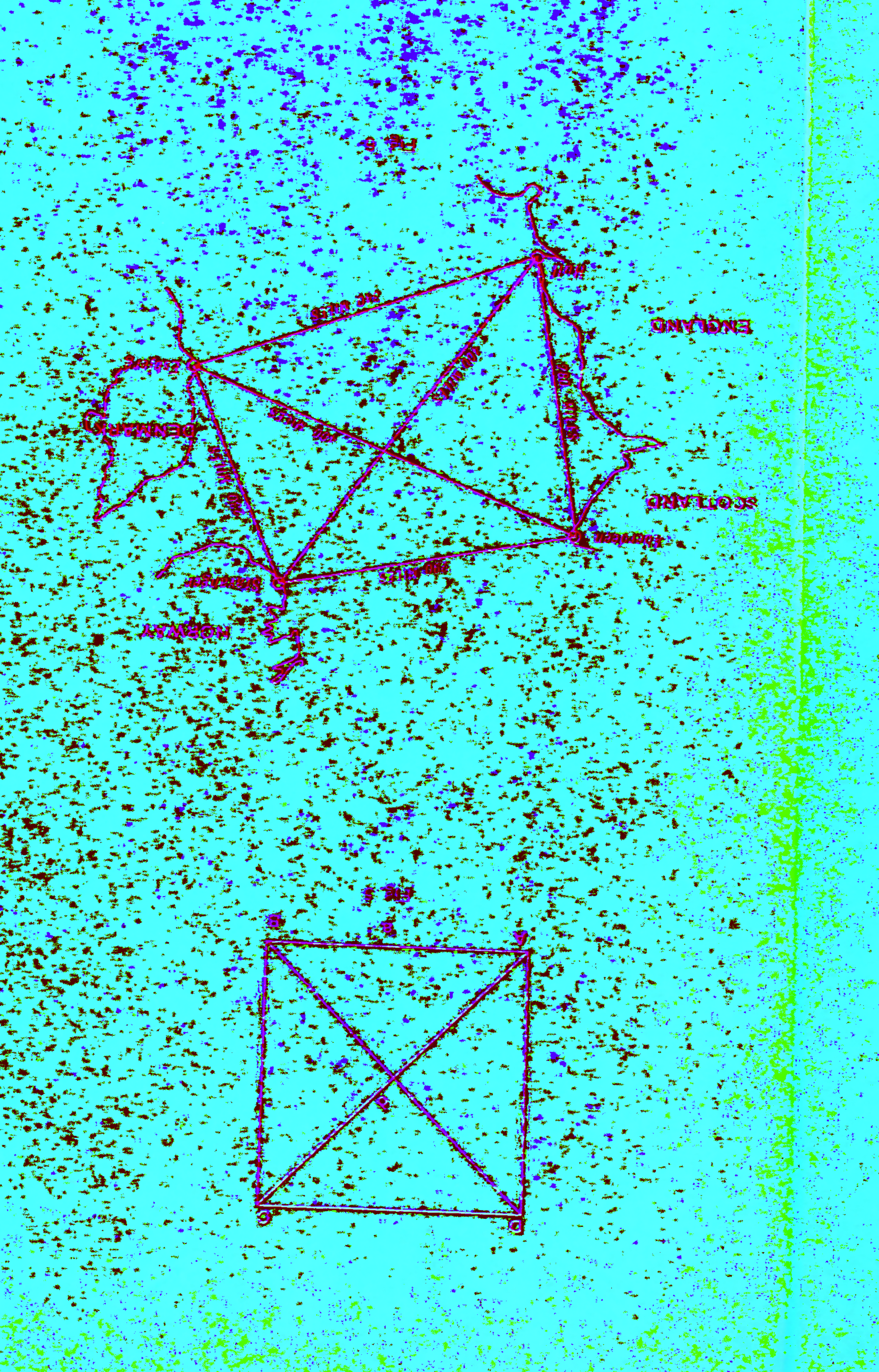






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ENGLAND
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SURVEYING FROM AIR PHOTOGRAPHS FIXED BY REMOTE RADAR CONTROL

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1. INTRODUCTION

During the last thirty years, developments in the taking of air photographs (and of mapping from them) have been progressive until, under present day conditions, no programme of topographical mapping for economic development can be satisfactorily undertaken without using them.

Radio has now come to the assistance of the surveyor, and doubtless this aid will become as equally indispensable as the air photograph. Developments in radar pulse technique during the late war produced devices of great accuracy for navigation and bombing. By this means it is now possible to position and fix air photographs accurately in space, and to range very long lines.

In the early days, air survey passed through many vicissitudes, partly due to over-enthusiasm of those advocating a method as yet immature, and partly due to caution and conservatism on the part of surveyors. The problems, not only of cost but also of air navigation and photography, made the desirability of its full employment slow to be realized. In the U.S.A. some years before the war the sheer economic necessity of dealing hurriedly with soil erosion and flooding problems resulted in an extensive programme of air survey. Canada, too, had a large programme. This intensive development and progress made during the recent war has removed all doubt as to the value of air survey.

The ideal of having truly vertical photography which presents a clear, undistorted picture of the ground, taken with full stereoscopic overlap from positions accurately related to it, can never be fully realized, but the nearer the ideal conditions can be fulfilled, the simpler becomes the surveyor's task in providing a desired standard of accuracy.

This paper shows the effect of the employment of radar technique on survey methods, and this effect, it is considered, will rank in importance with that of the establishment of systematically taken air photographs as reliable survey data. The result is a complete change in the scientific approach to air survey, although much research and development remains to be done.

Before air photography was used as an aid to surveying, topographical maps were prepared by accepted ground methods. First, a control network of triangulation was provided, whereby the positions of certain stations were accurately established in relation to the earth's surface and to each other. Topographical detail was filled in by plane-tabling, heights being measured by vertical angles or barometric levelling. The process was lengthy and progress was dependent upon climatic conditions since the survey work had all to be done on the ground.

The next stage of development was the employment of suitably taken air photographs linked geometrically but not scaled, and this resulted in considerable reduction of work in surveying detail on the ground, which could now be carried out at leisure from the photographs. Even though it was rarely possible to fly so that the photography approached the surveyor's ideal, ground control positions every few miles were sufficient for plan. For contouring, several heighted points were required per overlap unless a stereoscopic instrument capable of photogrammetric bridging, and therefore allowing some reduction, was used. The survey could be completed much more quickly than before, priorities of mapping be readily

switched in accordance with economic needs, and the photographs were available for general study.

The synchronization of radar fixes with the taking of air photographs enables the aircraft to be navigated to any desired position for photography and the position of the aircraft at the moment of exposure to be accurately established in relation to the surface of the earth. Thus quite apart from the economy resulting from accurate navigation (which is considerable), improvements in photographic technique and of survey measurement, coupled with the employment of radar for navigation and fixation of air photographs, now permit production of topographical maps to full survey specification with very much less ground control than was necessary before. Moreover, in some cases ground measurements other than those to the remote radar ground control stations can be entirely eliminated.

The essence of this application is that the control, previously fixed by ground surveys, can be very largely superseded by control points computed in ground position from radar fixes, altimeter readings and photogrammetric measurement, and, without actual access to the area.

The basis of application is given in this paper, the method described having been developed at the War Office between 1943 and 1945, in connexion with a requirement for the production of tactical maps in areas of South East Asia, where no ground control was available. Discussion is taken up to the derivation of control only, the experimental work which was carried out in conjunction with other workers and the adaptation of standard air survey methods being described in another paper.*

The photogrammetric methods for providing ground control from radar-fixed air photographs required considerable investigation on account of random tilts and altitudes. Various methods were evolved, particularly for minimizing computation.

The author was responsible for the research work from the survey aspect, and was assisted by Major E. A. Miskin, M.A., B.Sc., R.E. The work was carried out under the direction of Brigadier M. Hotine, C.B.E., Director of Military Survey, War Office, to whom acknowledgment is made for encouragement and technical guidance during the progress of the work.

2. MODERN DEVELOPMENTS IN PHOTOGRAMMETRY

2. (1) Basic flying requirement

The primary requirement for air photography is that the photographs should be taken vertically, at constant altitude, in strips exactly where required, with stereoscopic overlaps just sufficient to carry forward the survey triangulation along the strip and with lateral overlaps to enable the strips to be connected together.

2. (2) Tilt

Recent flying experience has been under operational conditions when, if tilts do not exceed $\pm 2°$ and ground height variations are not greater than 10 to 15 per cent of the flying height, the surveyor can ' make do '

* Hart, C. A. 1946. *Modern Methods of Mapping, including the employment of radio technique, and with special reference to Economic Development.* R. Soc. Emp. Sci. Con. i, 633.

with simple methods of plotting. The more tilt is reduced, however, the more economical the photography and the simpler the survey task. By the standard employment of automatic pilots in suitable aircraft for peace-time flying, with gyroscopic control of camera mountings, it is expected in the near future to reduce tilt consistently to ½° or less. Work is also proceeding on the instrumental measurement of tilt, which it is hoped to measure to at least this accuracy.

2. (3) The survey camera and its calibration

The employment of a properly designed and calibrated survey camera will ensure maximum accuracy of depiction of the image on the sensitive material of the film.

The new British F-66 survey camera with a 6-inch focal length lens on a format 9×9 in. has lens, non-distorting between-lens shutter, cone and register-glass all built as one unit, distortion being assessed for the combination. Accurately engraved collimating marks on the register-glass enable image distortions to be measured. Such cameras are now laboratory-calibrated, leaving only field checks to be made by the surveyor. Distortions, principal distance and principal point location are all required to about the nearest 0·01 mm.

2. (4) Materials and processing

The flying of a block of survey photograph involves considerable expenditure of flying time, photographic materials, and employment of photographic staff. Much technical effort is required from the surveyor before the final map can be produced. It is therefore essential to ensure that the most satisfactory photographic materials are employed and subsequently processed with great care to ensure minimum distortions.

The best results are obtained by using topographical-base film developed without stress and festooned to dry and cure for 24 hours before printing, although for work of slightly less accuracy drying on a drum without heat is satisfactory. For multiplex working, miniature diapositives are made on lantern slides from original film by means of a reduction printer designed in conjunction with the survey camera and projector lenses so that the projected image is distortion free. In one precise three-dimensional measuring instrument, the Wild autograph, a special refracting plate is inserted in the optical viewing system to correct the image positions on contact glass diapositives or negatives ; while for co-ordinate measurement in the stereocomparator, where prints are made on sensitized aluminium foil on which distortions are negligible, corrections are applied from a distortion chart appropriate to the camera.

Under properly controlled conditions, the ultimate differential distortions on topographical-base film should not exceed 0·01–0·02 per cent. Other materials such as regular nitrate base may give comparable results under certain conditions for a limited time, but are not satisfactory substitutes.

2. (5) Effect of distortions on survey measurement

Provided that the air camera is accurately calibrated, and that the best photographic materials are used and properly processed, it is now just about possible to conform with the surveyor's limit of 0·01 mm. 'want of

correspondence,' when the air camera is one with a graduated glass pressure-plate which enables distortions of image to be measured.

The fact that the surveyor can ' make do ' with less accuracy does not mean that he is by any means satisfied, since the better the photography, the higher can be the survey accuracy and the less the ground control required.

3. BASIC PRINCIPLES OF RADAR AND THE EFFECT OF ITS EMPLOYMENT ON AIR SURVEY TECHNIQUE

3. (1) Basic principles of radar range measurement

For air survey purposes the distance is measured between the aircraft and each of two accurately located ground radar stations by means of radar pulse signals synchronized with the operation of the survey camera. From these data the position of the aircraft may be determined in relation to the spheroid if the approximate altitude at exposure is known (fig. 1)*. Distance is measured in terms of the interval of time between transmitted and return pulses as indicated on a cathode ray tube. In the methods so far employed for survey (' Gee-H ' and ' Oboe '), the aircraft follows a circular track at constant range from one station, limiting range being about 250 miles.

3. (2) Effect of employment of radar on air survey technique

Radar fixes are sufficiently accurate to position an aircraft very nearly where a photograph is required so that reliable navigation can be achieved, in addition to recording that position with accuracy significant for topographical mapping.

The position of each radar-fixed photograph may be arranged so that the strips are laterally matched, thus allowing of analysis both in the direction of flight and transversely, and employment of ordinary survey traversing methods with little or no ground-determined control. Moreover, since radar fixes establish scale and position the employment of suitable aircraft permitting accurate relative altitude determination enables accurately relative contours to be produced similarly. To obtain full peace-time mapping standards, some plan and height control will be required, but much less than before.

If there are coastlines, stretches of inland water, or other height control in the area to be mapped, absolute altitudes may be established and extensions made in areas where there is no control. Control established by photogrammetric analysis from laterally matched photographs on strips overlapping by some 60 per cent utilizing radar fixes, accurate altimetric differences and approximate altitudes enables reliable relative contours to be plotted with reference to an approximate datum.

3. (3) Methods of measurement, synchronization of readings, and sources of error

Measurements are made either directly in time or in distance based upon a mean rate of propagation.

For ' Gee ' and also for ' Gee-H ' which has been employed for survey, the ' Gee-unit ' selected arbitrarily, is represented by the distance

* All figures referred to in this paper will be found at the end of the paper i.e., facing page 660.

traversed by the radio waves in 66·66 μ-secs, the full Gee value (i.e., double-path distance) being slightly less than 20,000 metres. For survey, it is found convenient to refer to the unit as the single-path distance (i.e., 10,000 metres approximately). The slight changes of rate of propagation are insignificant for purposes of ordinary navigation, but for survey purposes these must be taken into account. In one system where a fairly low-frequency radio technique is employed to measure the difference of distances from two pairs of ground stations, measurements are made of ' phase differences,' and similarly a low-frequency pulse method is used for navigation where ranges are 600–700 miles or more since transmission is not affected by the necessity of optical paths. The accuracy is, however, much reduced, but is nevertheless accurate enough for reconnaissance surveys up to this range, given a suitable arrangement of stations.

For Gee-H, a record is made by means of an automatic observer (synchronized within a few milli-seconds of the main camera exposure) which photographs the necessary instruments, including a second C.R.T. in parallel with that operated by the navigator (see fig. 2). The two dials, lower left, are desynn recorders of remote drift and fore-and-aft levelling adjustments made by the navigator, and tilt indication by gyro-controlled artificial horizon is seen top centre. The aircraft is kept on its track by flying it so that the upper pair of strobes is aligned at the correct track reading, while the lower pair are kept aligned by the navigator so that the air camera and automatic observer can be released by him at the correct reading. The close scales are the slow time-bases, giving whole ' Gee-units,' while the faster time-bases have calibration pips at 0·1 ' Gee-unit ' intervals. Measurements are taken from the original films under magnification by a method which also corrects for any slight mis-alignment of the strobes. Systematic readings can be made with a mean accuracy of about ±·0025 ' Gee-units,' i.e., 25 metres.

In the case of ' Oboe,' the ' track ' and ' rating ' ranges are read at the two ground stations respectively, which are known as the ' Cat ' and ' Mouse.' The method of setting up is much the same as for ' Gee-H,' but the time-base is much faster, and the graduations are in miles. In a current series of experiments, cine-cameras are being employed for recording the actual range readings.

When the new British survey cameras are in use, most of the instruments will be incorporated, leaving mainly radar ranges to be recorded in the automatic observer.

Accurate distance measurement by radar is subject to errors from various causes.

(i) *Errors in measurement of distance as ' time '*

The measurement of time by radar pulses at present allows accuracy of measurement to about ±0·1 μ-secs, or about 17 metres in single-path distance. For Gee-H, the random error is about twice this.

(ii) *Errors of recording the reading*

The accuracy of measurement of the range at the instant of exposure is linked with delays in recording and inaccuracy of taking the reading. In the ' Gee-H ' automatic recorder the lag of the electrical method

employed is not more than a few yards and is small compared with the accuracy of reading, which is not greater than ±25 metres.

(iii) *Errors in assessing 'delay' or time taken in transmission through the electrical circuits*

To allow for variations in signal strength it is customary to arrange the circuitry so that the interval of time between receipt and re-transmission can be maintained constant. This is called the 'delay' and in the case of Gee-H random errors of ±20 metres are likely.

(iv) *Errors in the speed of propagation*

The high frequencies used for survey measurement are effective only within optical range. Variation in the rate of transmission due to ground irregularities is uncertain, but appears to be about one part in 10^4. The most significant effect is, however, due to refraction. Under widely differing climatic conditions this effect is not greater than about 1 part in 10^4 when the aircraft is at an altitude over 10,000 ft and the range is optical. The method of application at present is either to assess a mean rate of propagation for a particular region according to range and aircraft height, or to apply a correction for the curved refracted path. The error introduced by these assumptions does not amount to more than a metre or two and is tolerable for aircraft fixes used as central for topographical mapping. The requirement is much more stringent for static observations, and much greater and unknown variations due to refraction are experienced near the ground, so that further research is required.

(v) *Total effect of errors*

At the present time it is possible under suitable conditions to reduce the total random errors to about ±20 metres (with 'Gee-H' about ±50 metres). Any systematic error can be eliminated by calibration.

3. (4) REDUCTION OF SLANT RANGE TO ARC DISTANCE ON THE SPHEROID AT M.S.L.

The distance measured by radar is the length of the path followed by the radio waves in terms of the time taken at varying velocity. For instance, if the distance from aircraft flying at 15,000 ft to a ground station at sea-level is approximately 150 miles, then the mean velocity of propagation for Western European conditions may be taken as 186,222 miles per second. Tables have been prepared for determining both chord (K) and arc (D) distances from the straight-line slant distances (L), using a mean radius of curvature of the earth (R). The error caused by this assumption is less than a metre for working ranges.

$$\text{chord distance } (K) = \sqrt{\frac{L^2-(h-s)^2}{\left(1+\frac{h}{R}\right)\left(1+\frac{s}{R}\right)}}$$

(h and s being the altitudes of aircraft and ground station respectively).

$$\text{arc distance } (D) = K+\frac{K^3}{24R^2}+\frac{3K^5}{640R^4}+$$

Various other formulae are available for direct conversion from slant

range to geodetic distance, suitable for geodetic work, but to obtain any advantage from their use, observations would have to be spread over at least several days.

3. (5) Calibration

Careful survey calibration is necessary and is best achieved by flying the survey aircraft several times across the base-line joining the two accurately located stations. For 'Gee-H', ranges from each station are recorded several times on the automatic observer during each run, the minimum sum of the ranges after reduction to sea-level, giving the distance between the stations, inclusive of the sum of the delays, and this can be compared with the true distance. Similarly, by flying across the extended base-line at either end, the difference between the delays at the two stations is determined. Eight or ten runs should allow the value of the delay at each station to be assessed to a few metres, thereby eliminating random errors.

Such discrepancies as exist may be attributed to variations in propagation rates rather than to failings in the method of measurement. Unfortunately at the moment it is impossible to separate the problems of propagation and delay, for the measurement of very short distances by radar (which would minimize propagation errors) is rendered impracticable as a result of excessive signal strength and consequent fluctuations in delay.

This method of calibration flights, introduced during our early experiments, has become the standard method for radar ranging of long lines subsequent to calibration.*

3. (6) Computation of fixes; accuracy of coverage

Knowing the arc distance on the spheroid from the aircraft to each accurately located ground station, it is possible to establish the aircraft position. As a first step it is necessary to compute, by a standard method, the length and azimuth of the base joining the two stations. For technical reasons with 'Gee-H' the ground receiving and transmitting aerials cannot be at one point, but it is satisfactory for all practical purposes to take the station as the *mid-point* between the two aerials (fig. 3) (giving a constant delay whatever the bearing), the error never amounting to more than a metre within practical limits.

The computation of fixes is quite simply carried out in geographical co-ordinates, with sufficient accuracy, by solving the plane triangle, adding spherical excess for a mean radius of the earth, and so determining the azimuth of one side of the triangle. The aircraft position is then found by distance and azimuth computation from both stations thus providing a check. This method is accurate over normal ranges to a metre or two.

An error in measurement of either or both ranges results in a linear fix error of

$$\frac{\sqrt{e_1^2+e_2^2-2\,e_1\,e_2\cos\theta}}{\sin\theta}$$

where e_1, e_2 are errors in measured distances from stations 1 and 2 respectively, and θ is the angle of cut of the rays at the aircraft. An

* Hart, C. A. *Ibid.*

indication of the coverage to be expected at any required altitude is obtained from theoretical considerations but usually, for planning purposes, it may be taken that the range is about 150 miles for an aircraft flying at 10,000 ft. and 250 miles at 30,000 ft. Achievement of this range is dependent upon having the ground stations on high unscreened sites, and upon suitable atmospheric conditions.

The survey coverage from a pair of stations is dependent upon flying height and standard of accuracy required, and may be planned quite simply on the above basis, the minimum suitable circular track radius being about 30 miles. Accuracy of fix, rather than range, is usually the limiting factor, except where radar is being used solely for tracking, when the coverage area is much greater.

4. PREPARATION OF RADAR-CONTROLLED FLYING PROGRAMMES

4. (1) Outline

Quite apart from fixation of air photographs, radar-controlled tracking gives a method of obtaining efficient and economical air photo cover, where no medium-scale maps exist, and is also advantageous in areas where they do. So far with the systems employed it is necessary to fly the strips in circular paths, and although it would be advantageous topographically and for plotting to have straight strips in a selected direction, no particular difficulty has been experienced, photogrammetrically, for strips of 30 miles radius or more.*

The block can be flown from a programme of radar-fixes without reference to the ground, not only for navigational purposes, but also to position each photograph. For operational mapping purposes, where reduction of time after photography is of paramount importance, the photographs can be taken so nearly to the pre-computed geodetic fix, that simple interpolation can be resorted to.

4. (2) Navigation for strip photography

For planning strip photography only, one ground station is adequate for navigational control if there is enough topographical detail already mapped for identification of the beginning and end of each run (see fig. 4). When necessary the terminal points can be established on the chart as ranges from the second station. The area of photography can be planned on a base map as here (originally 1/500,000 air map) or upon a blank graticule.

The circles represent ranges in ' Gee-units ' from each station, each one being moved in by 0·1 unit to allow for the delay. No account need be

* Other systems, dependent upon measurement of ' phase difference ' or radar pulse measurement of difference of distances may be used for navigation along hyperbolic tracks which become sensibly straight at some distance from the station, and also for fixation. For surveys in undeveloped areas these suffer from certain practical disadvantages at present, and accuracy of fixation is generally less.

taken of variations between slant range and arc distance for positioning the block, and a 'Gee-unit' may be taken to represent 10,000 metres of distance for planning purposes.

From scale of photography and size of photograph, the track readings are determined according to the desired lateral overlap. Terminal points can be selected with sufficient accuracy, when the angle of cut is as small as 10°.

4. (3) Planning photo-fixes from a chart

A chart such as that in fig. 4, at its original scale, is adequate. To ensure accurate positioning of the strip one track value is computed from geographical co-ordinates, and range change per overlap added or subtracted. The required spacing along track is expressed in terms of range change from the second or 'rating' station between exposures, and is computed simply by assuming a mean angle of cut for each two or three strips.

Thus a complete flying programme can be drawn up which, if adhered to, will give not only the desired lateral and forward overlaps within narrow limits, but will provide *matched* lateral overlaps.

Fig. 5 shows the relationship between planned and actual photo strips for the 'Gee-H' Anglesey Survey as planned from fig. 4. The ground stations were near Swindon and Matlock, the average ranges being 160 and 110 miles respectively. The maximum variation from the 60 per cent overlap was ±4 per cent both longitudinally and laterally, the photographic scale being 1/52,500. Using 'Oboe' a maximum track variation of ±6 per cent was obtained for a photographic scale of 1/17,500.

4. (4) Geodetic pre-computation of photo-fixes

The survey experiments were undertaken primarily from an operational standpoint and the closeness with which the flying programme could be fulfilled led to an investigation of the possibilities of geodetic pre-computation with simple interpolation to actual fix. By this means any delay in the rapid production of maps due to time taken for fix computations could be avoided. Several methods of computation have been developed, and have shown this approach to be desirable operationally. Since the most promising photogrammetric methods necessitate the computation of only a proportion of the fixes, it is, however, generally quicker in *total* time to select and compute only those required after photography, and the writer recommends the method in para. 4. (3) above for normal peace-time surveys.

5. SURVEY TECHNIQUE FOR DERIVATION OF GROUND CONTROL FROM RADAR FIXES AND ALTIMETER DIFFERENCES

5. (1) Outline

The procedure for producing a basic ground control involves determination of (i) relative tilts, (ii) absolute tilts from relative tilts and altimeter differences, (iii) basic plan and height control.

Survey technique for mapping from remote radar control is by no means

limited to stereocomparator work, since the relative tilts may be set and measured in three-dimensional instruments, while under certain conditions it may be possible to use the multiplex for determination of absolute tilts and derivation of ground control as well.

5. (2) Determination of relative tilts

The three-dimensional theory of air survey is based upon Fourcade's 'want of correspondence' principle that the two images of the same point of ground detail in a stereo-pair have the same polar bearing, so that if the differences of distance in the *y*- direction from the base-line are measured for an arrangement of points as in fig. 6, then the relative orientation of the two photographs of the pair can be found in respect of :

(i) the fore-and-aft tilt in relation to the base-line
(ii) the lateral tilt of one photograph with respect to the other
(iii) the swing of each photograph with respect to the base-line.

For stereocomparator or grid stereoscope work a modification of the Hotine method has been employed.* A first approximation is computed from the observations, while further approximations are self-checking and can result in an accuracy of one or two minutes, given minimum unknown distortions. An experienced stereoscopic observer is required, since inaccurate observations will not show up in the computations, and he must be able to read 'want of correspondence' to 0·01 mm. on accurate foil prints.

If a three-dimensional instrument such as the stereoplanigraph or autograph is used, the relative orientation of the pair of photographs may be established and measured by a drill which eliminates the 'want of correspondence.'

5. (3) Determination of absolute tilts from relative tilts and altimeter differences

(i) *General.* Absolute tilts may be determined by a variety of methods from relative tilts and accurate altimeter differences.

Three approaches to the problem have so far been tried :

(*a*) Given lateral overlaps of approximately sixty per cent, so matched that the angle between lateral and forward air-bases is between 60° and 90°, the datum may be defined for a common overlap by the slope of the plane containing the three air bases. This is called the 'three corner' method.

(*b*) Summation of relative tilts along a strip enables absolute fore-and-aft tilts to be found on the assumption that there is a constant correction for a particular set of flying conditions. Absolute lateral tilts are established by similar determination of fore-and-aft tilts along the transverse strips provided by laterally-matching photographs. Alternatively it may be assumed that the sum of all the lateral tilts is a constant depending on the flying conditions, giving approximate values for a single strip, and for this method lateral overlaps need not exceed 20 per cent or so given approximate

* Hotine, M. 1930. *Surveying from air photographs*, Constable, London.

relative heights, and it is suitable when the aircraft is of the Mosquito type. This approach has not yet been fully investigated.

(*c*) Setting absolute tilts instrumentally. Preliminary experiments indicate that the multiplex after modification may give satisfactory results under certain conditions.

(ii) The ' three-corner ' method originally tried with the ' Oboe ' Block has proved very successful, with good photography. A brief description follows :

With sixty per cent matched forward and lateral overlaps the principal points of three photographs, P_1, P_2 and P_3, appear on a common overlap (fig. 7). Relative tilts between photographs 1 and 2, and 1 and 3, will have been determined previously in relation to the air bases $S_1 S_2$ and $S_1 S_3$ respectively. The available data consists of the radar fixes for the camera stations S_1, S_2 and S_3, and the altimeter differences of the three stations, and approximate absolute altitudes. The absolute tilts of the three photographs can be found with accuracy comparable with that of the definition of slope of the station plane ' $S_1 S_2 S_3$,' by altimeter differences.

Absolute fore-and-aft tilt in the directions of an air-base is determined from the relative tilt of the photograph to, and the inclination of, the air-base. The latter is found from the radar fixed base-length and the altimeter difference between the stations, and is satisfactory when a steady aircraft is used, otherwise a summation method must be used along a strip to reduce the effect of random errors.

Absolute tilt of the common photograph is determined in the two directions $S_1 \rightarrow S_2$ and $S_1 \rightarrow S_3$ and is resolved as necessary.

5. (4) Determination of basic plan and height control

For the ' three-corner ' method, four points common to the three photographs are selected, with generally an additional one near the principal point of the central photograph ; and these, if not points chosen for ' want of correspondence ' measurements, are observed during the original stereocomparator readings. Three points are essential to the method, the remainder being used as checks. Space co-ordinates, relative to the air-base ($S_1 S_2$) as X axis and the perpendicular through the principal point of the left-hand photograph as Z axis, are first computed from the photo-co-ordinates and absolute tilts. The X and Y co-ordinates are then transformed through an angle β (the bearing of $S_1 S_2$ as deduced from radar fixes of S_1 and S_2), and applied to the air station position to give ground co-ordinates of the selected point.

By using fore-and-aft and lateral overlaps it is possible to check determinations of points common to several overlaps.

The Z co-ordinates of the control points will provide differences in height which can then be applied to a selected datum to produce height control.

In addition to these points, it has been found desirable to have the principal point accurately located in relation to the radar fix where control is computed, and this is readily found from a knowledge of the aircraft height, which need not be very accurate since absolute tilts are usually small, and the error arising will be much less than the probable error of a radar fix.

5. (5) Effect of errors in measurement on plan and height control

Accuracy of derivation of control depends upon a number of factors and table I has been drawn up showing the effects of errors of a given magnitude upon computed plan positions and ground heights under the normal conditions encountered in survey photography (i.e., tilts not exceeding 2°, photo-scale about 1/30,000, focal length 6 inches). This table gives a general indication only of the relative importance of the different quantities involved, and the values given, unless otherwise stated, are for a *single overlap*. Over a block of photographs some of these will be averaged out and some will accumulate so that final accuracy attained will be largely dependent upon the arrangement of the block and the amount of ground control available, if any.

An immediate conclusion from the table (on p. 661), is the imperative need for accurate calibration, both of the radar equipment and of the altimeter.

Random errors in radar distance measurement are still the largest source of inaccuracy, but do not appreciably affect the heighting. A high standard of heighting may be maintained provided that individual sources of error are kept within the limits indicated in column 1 of the table, that absolute tilt is determined by averaging out altimeter differences over a sufficiently large number of photographs, and that the value of the air-base used in height computation is carefully chosen.

6. CONCLUSIONS

Having determined a sufficient number of control points from photogrammetric data and radar fixes, it remains to adapt survey techniques so as to utilize this control to the best advantage, and produce maps on which the topographical detail is located both relatively and absolutely to desired cartographical standards.

Normal standards for peace-time 1/25,000 mapping specify maximum errors of the order of 15 metres in position and $2\frac{1}{2}$–5 metres in height, and for 1/50,000 mapping, approximately double these quantities. The table shows that some latitude may be permissible in the computation of plan control from photogrammetric measurement (e.g., tilts accurate to 5–10 minutes would suffice), but there can be no relaxation in the standards at present demanded as far as heighting is concerned.

Even under the most favourable conditions this specified peace-time accuracy cannot yet be attained by remote control methods, since the best results to be expected for computed control points gives random errors of the order of $\pm$20 metres in range, and $\pm$10 metres in relative height, maximum range being 200–250 miles.

Modifications of survey plotting arise from

(*a*) direct establishment of approximate scale from radar fixes
(*b*) necessity of assembling the blocks of photographs in such a way that the effect of random errors in the radar fixes used for control is minimized.

Experimental work carried out by the War Office is discussed elsewhere * and, where mapping is to be carried out without direct reference to the ground in that area, it appears so far that the most satisfactory results are obtained by computing basic control at intervals of approximately seven overlaps, both forward and laterally, consisting of five principal point or detail control points in each corner of the block. Slotted template assemblies over the whole block after local adjustment of each group, have proved successful as also have adjusted principal-point traverses on four or five computed principal points per block. When contours are required, the multiplex has proved the only really successful method for bridging heights. If tilt and height distortions are excessive, the slotted template assembly may be based on plumb-points from approximate absolute tilts or plumb-point traversing may be used.

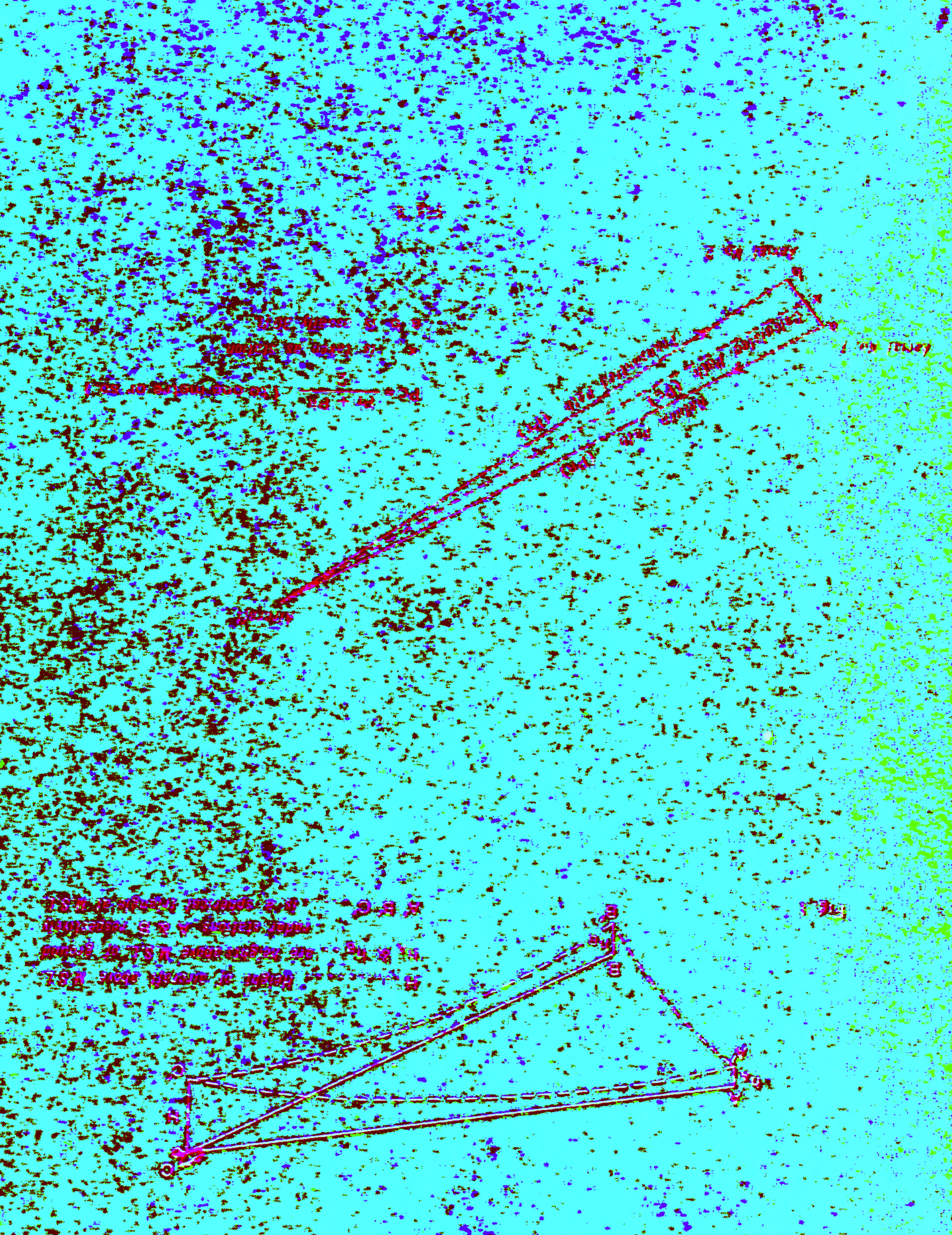
Although maps at 1/25,000 to 1/50,000 can be made to a reasonable standard of accuracy without direct reference to the ground, mapping to full peace-time specifications at present requires a small amount of ground control when radar fixes are employed, but on a very much reduced scale.

With reduction of tilt, or its accurate measurement, it is likely that the labour of determining control will be much reduced.

Hasty maps of a lower order of accuracy may be prepared by slotted template assembly on uncorrected radar fixes.

Much research work remains to be done from all aspects, in order to discover the most accurate and economical methods for production of the ultimate map.

* Hart, C. A. 1946. *Ibid.*



AUTOMATIC OBSERVER RECORD



Scale = 3/4 full size (approx.)

Fig. 2

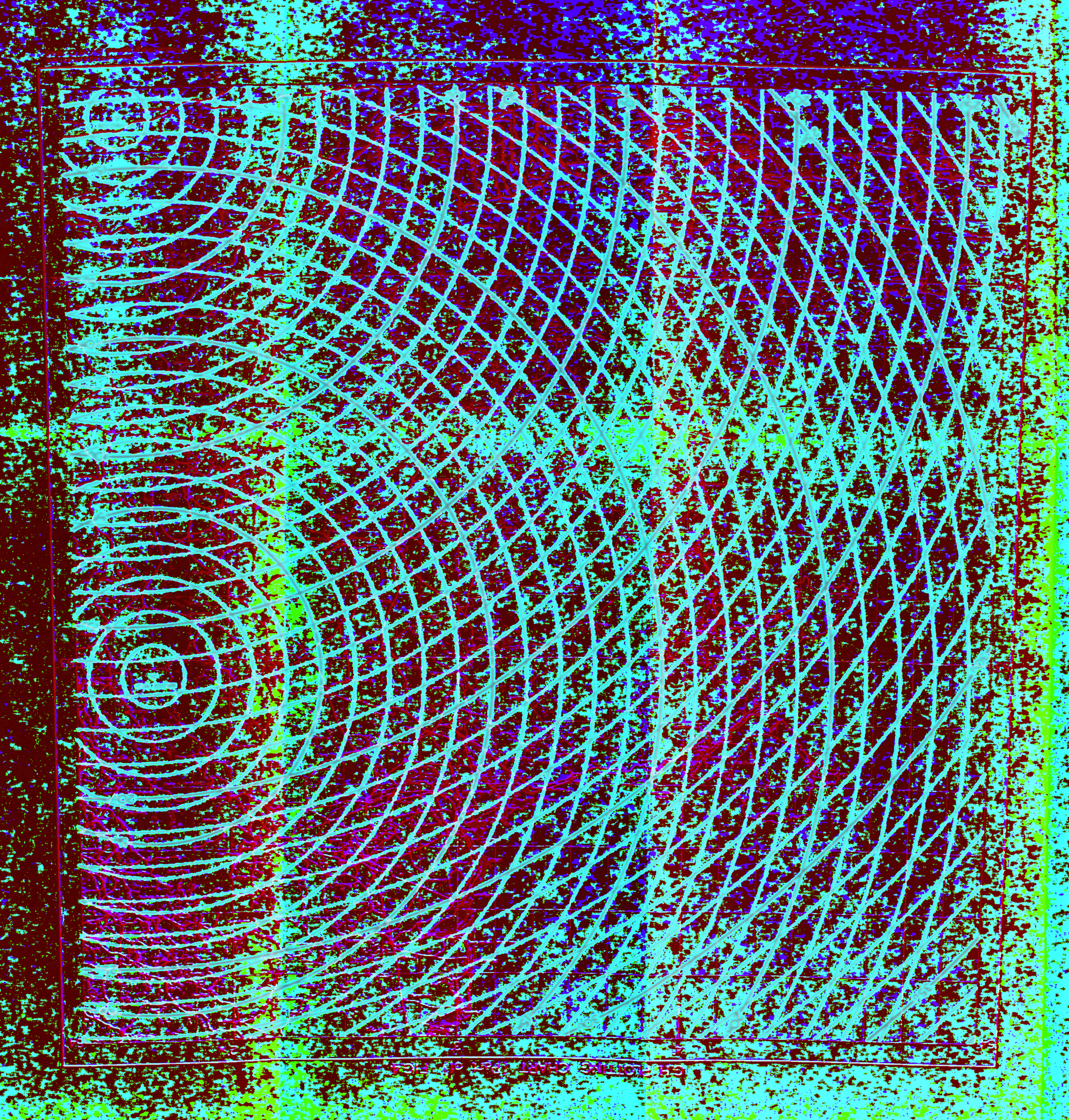


FIG. 5

TEST
EX 216
ANGLESEY





TABLE

Error of	In	Results in the following errors in metres	
		Plan position	Height
100 metres	Slant range (absolute value)	100–200	
±20 metres	,, ,, (random errors)	20–40	
100 metres	Altimeter height (absolute value)	Overall scale error	100
±5 metres	Altimeter differences (i) If absolute tilt determined from a strip of 10 photos	1	2
	(ii) If absolute tilt determined from a single overlap	10	15
20 metres	Air-base (i) If air-base is used only for computation of base inclination from altimeter differences		0·2
	(ii) If single determination of air-base from two radar fixes is substituted in parallax equation		35
0·1 m.m.	Focal length	2	2·5
0·1 m.m.	Calibrated P.P. position	3	
0·02 m.m.	Stereocomparator reading	1	1
1 minute	Fore-and-aft tilt	1·5	2
1 minute	Lateral tilt	1·5	0·5
1 minute	Orientation of photograph in Stereocomparator	1	1

MAPPING AND EXPLORATION BY AIR, INCLUDING THE USE OF RADAR TECHNIQUE IN THE NATIONAL SURVEY—POSITION IN AUSTRALIA IN APRIL 1946

By F. M. Johnston

(Commonwealth Surveyor General)

Before the outbreak of war in 1939 practically all geodetic and topographical survey work was carried out by the Australian Survey Corps whose personnel at that time totalled approximately thirty. Commonwealth Civil Departments and State survey organizations were occupied mainly with cadastral and engineering work.

In the circumstances, very little of Australia was adequately mapped. During the war however, the Australian Survey Corps was expanded to a strength of approximately 2,000. This organization engaged in mapping activities in Australia in addition to the various operational theatres. Civil departments assisted in the topographical mapping of Australia during the war period and have continued their activities since.

In January 1945, on the initiative of the Commonwealth Survey Committee which comprises representatives of the Commonwealth Departments of Navy, Army, Air, Interior and Civil Aviation, a conference attended by representatives of Commonwealth and State mapping authorities was held in Canberra, A.C.T.

This conference recommended the formation of a National Mapping Council, also the appointment of the Commonwealth Surveyor-General, Department of Interior, Canberra (Mr F. M. Johnston), as Director of National Mapping. The recommended composition of the National Mapping Council was the Commonwealth Surveyor-General (to be Chairman), a representative of the Commonwealth Survey Committee (Director of Army Survey—Col. L. Fitzgerald), and the Surveyors-General of the six Australian States.

The functions of the National Mapping Council are :—

(1) To assist in the implementation of the decisions of this and subsequent Conferences.
(2) To co-ordinate and correlate mapping on a national basis.
(3) To determine standard methods and minimum accuracy of requirements of trigonometrical surveys.
(4) To determine approved methods and minimum standards of accuracy for photogrammetry and cartography.
(5) Subject to reference to appropriate authorities, to recommend mapping priorities where Commonwealth assistance is involved, except in the case of Service requirements.
(6) To recommend the allocation of Commonwealth funds provided for national mapping.

The recommendations of the Conference have been adopted by the Commonwealth and the six State Governments and the necessary staff

and organization required for implementation are now being arranged. A Deputy Director of National Mapping (Mr B. P. Lambert) has been recently appointed and he is proceeding abroad in May 1946 to obtain data on recent developments in survey and mapping technique, particularly in respect to air surveys.

The Topographical Map System for Australia is based on the 1/1,000,000 International Map (Sheet size 6° Long. × 4° Lat.) which are being drawn at the Department of the Interior, Canberra.

The Army Series divides the International Maps into sheets on scales of 4 miles and 1 mile to one inch, drawn on a Transverse Mercator Projection. Several of the States have already adopted the Army Series and the National Mapping Council is bringing pressure on the other States ' to fall into line ' in their future mapping.

The ground control will be provided by triangulation or by standard traverse in terrain unsuitable for trig work. The use of radar for such purpose is dealt with hereunder.

Whilst a certain amount of triangulation has been carried out under the control of each State Government, the Army Survey Corps has completed part of the main chain extending from near Brisbane across N.S.W. and Victoria into South Australia to the south of Adelaide. It is anticipated that further triangulation will be carried out by the Army and Commonwealth and State Departments.

Air photographs generally on a photo scale of about 1/30,000 are being taken by the R.A.A.F. for both Army and civilian mapping purposes. The States of Victoria and Tasmania have entered into contracts with private flying companies for the supply of air photos covering most of those States. At the present moment, only a small percentage of Australia has been photographed from the air.

Both vertical and tri-metrogon (oblique) photographs have been taken, being plotted by either graphical or slotted template methods. Whilst very little provision has so far been made for modern air photo plotting apparatus, it is expected that Multiplex equipment will be obtained from England at a fairly early date.

Consideration has been given by the Commonwealth Survey Committee to the use of radar and it is anticipated that the R.A.A.F. Survey Flight will shortly be provided with standard English service equipment.

The Division of Radio Physics of the Council of Scientific and Industrial Research located at the Sydney University is carrying out investigations into the application of radar with the following end in view :—

(*a*) The construction of equipment for the precise measurement in an aircraft of the length of a base line some 300 to 500 miles long. It would be used for linking up those areas which are already well surveyed and for producing a long base triangulation of the whole of the Australian continent.

(*b*) The ground control of survey aircraft by methods similar to those in use in the United Kingdom and the United States.

(*c*) Study of the velocity of propagation of radio waves over a 30-mile link in the vicinity of Sydney. This investigation is expected to lead to more accurate methods of distance measuring and to means of correcting for variations in velocity with atmospheric conditions.

MORNING SUBJECT (e)

DISCUSSION OF MEASURES FOR IMPROVING SCIENTIFIC INFORMATION SERVICES WITHIN THE EMPIRE. SUBJECTS TO BE DISCUSSED INCLUDE INDEXING, ABSTRACTING, SPECIAL LIBRARIES AND MICROFILMS

Steering Group

Chairman—Dr C. J. Mackenzie

Recorder—Professor R. S. Hutton

Sir Alfred Egerton, Sec. R.S.
Dr E. Marsden, F.R.S.
Sir David Rivett, F.R.S.
Professor B. F. J. Schonland, F.R.S.
Dr H. H. Storey, F.R.S.
Mr D. N. Wadia.

Report

Owing to the rapid growth of scientific research, with the resulting promiscuous distribution of original papers among many journals, the improvement of indexing and abstracting services is a matter of first importance.

The Conference discussed many aspects of the problem and agreed that better organization and much greater financial assistance for these services were required.

The difficulty of securing access to publications resulting from work in all parts of the Commonwealth could be met largely by following the example of India and by preparing abstracts covering all the work done in the individual Dominion.

In judging the value of the short, indicative abstract as distinct from the longer, informative abstract, the needs of the scientific user should be kept always in mind.

Attention was drawn to the need for translating and making accessible publications in the less well known languages.

Considerable attention was given to the point that the scientist needs access to reproductions of original papers and that such papers were usually buried in journals containing other matter in which he was not interested. The possibilities of greatly improving the facilities for reproducing original individual papers as separates were considered. The microfilm in this connexion offered opportunities. There was scope for an approach to publishers and copyright-holders with a view to securing their co-operation in permitting microfilm and other methods of reproduction to be more widely used.

There was discussion of the need for the centralized indexing of scientific literature and evidence was forthcoming as to the small proportion of such literature of which abstracts were made. As an aid to more comprehensive abstracting, centralized indexing was felt to be necessary.

The weaknesses in information services were found partly in respect of particular territories and countries and partly of particular fields of science. It was, therefore, not logical to confine projects for improvement to the Commonwealth alone. Co-operation with the authorities in the United States and elsewhere was most desirable. Proposals for further consideration of the problem are contained in the following recommendations.

Note.

Matters of allied interest were considered under subjects (f), (k) and (l).

General recommendation

The Conference invites the Royal Society at an early date to convene a conference of the libraries, societies and institutions responsible for publishing, abstracting and information services, in order to examine the possibility of improvement in existing methods of collection, indexing and distribution of scientific literature, and for the extension of existing abstracting services. The Conference would pay particular regard to the cost of such services and to the need for funds from government sources for their support.

In the proposed conference :

(a) Representatives of the appropriate authorities in the Dominions, India and the Colonies should be included, together with observers from the U.S.A.

(b) The interests of scientists as users of scientific information should be especially considered.

(c) Consideration should be given to the abstracting of Dominion journals locally, for transmission to the main abstracting bodies in the United Kingdom.

Special recommendations

1. Consideration should be given to the establishment of a network of information services throughout the Dominions. Such a network would provide central focal points and for a two-way transmission of matter (either direct or through existing local centres adapted for the purpose).
2. In view of the need of the scientist for possession of individual scientific papers on his own subject, the possibility of the publication, classification and distribution of papers in separate form or as reprints should be considered.
3. The issue of occasional reviews of special branches of science, both for the specialist and for the general scientific reader, is considered desirable as a supplement to other forms of publication.
4. The extended provision of microfilm and other forms of documentary reproduction is considered important for the rapid transfer of information throughout the Commonwealth. An economic service for the purpose requires centres in the United Kingdom and in each of the Dominions.
5. The Conference recognizes that the qualifications of staff in scientific information services and special libraries call for special training and selection, and recommends the provision of facilities for increasing the number of properly trained staff.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Sir David Chadwick

Sir David Chadwick endorsed Professor Bernal's approach to abstracts : namely, from the point of view of the user. The justification of abstracts is to serve the current needs of the scientist. Their historical value is secondary. The needs of the user are paramount. Those needs should set the form and method of the abstracts. Those needs depend both on the nature of the branch of science in which a man is engaged and on the conditions under which he works. A form of abstract adequate for an astronomer with a good library to hand would be useless for an entomologist working in a colony or in the field. Another point is the general home language of most of the users. For readers of English it is often right to give fuller notice to a paper printed in Russian than to one in English or French. It is not possible to organize a service to meet the needs of each individual scientist, but it is possible to organize a service directed to the needs of very fairly defined groups of scientists ; and, moreover, one which gives the ' follow-up '—by supply of reprints, etc.—which Professor Bernal rightly stresses. The bureaux are centres of information designed to serve the needs of certain fairly defined groups of scientists. Abstracting is their chief tool, not their whole being ; yet their journals go to most countries of the world on their merits. It is not claimed this is the only method. Science is varied. One never knows where it will break out next. Needs vary. Scientists above all should treasure freedom and flexibility. Much more could be said, but the assumption underlying many proposals that the needs of all scientists can be adequately met by one form of abstracts prepared, perhaps anonymously, but centrally sorted is open to the gravest doubt.

Mr J. E. Cummins

Mr J. E. Cummins (Australia) agreed with previous speakers that there was need for improvement in abstracting and bibliographical services. The discussion, however, had tended to limit the functions of information services to abstracting, indexing, bibliographical and documentation work. In Australia and in some of the other Dominions the concept of information services was much broader and in general documentation and allied work was an important tool of the information service. In Australia one function was the provision of scientific and technical information in response to inquiries from scientific workers and from industry using literature as the main source of information. Seventy per cent of secondary industry in Australia was based on small companies, not provided with scientific or

highly trained technical staff. In addition to the provision of information in response to requests, the information service must be dynamic and keep ahead of progress and as necessary provide, without requests, critical summaries of information on new scientific developments. This requires specially trained staff and mention was made of Sir David Rivett's suggestion of recruiting staff from research laboratories, utilizing personnel whose natural curiosity and flair for research had diminished.

Other functions included the distribution of governmental and other reports, not covered in abstracting or indexing journals, the maintenance of close contact with overseas liaison offices, the editing and distribution of publications, the abstracting of local publications, the provision of translating facilities and the preparation of documentary films, etc.

The provision by the British Commonwealth of central information services was urged, such that these services would act as a centralized source for initial requests or contacts between the members of the Commonwealth. Such services would overcome some of the documentation difficulties enumerated by previous speakers. Instead of concentrating abstracting services in the United Kingdom, it was suggested that consideration should be given to each Dominion undertaking the abstracting of all its local publications. There are difficulties, but in view of the present close association of governments with scientific research, such abstracting could probably be organized and undertaken under government auspices or by government information services.

Sir Alfred Egerton

Sir Alfred Egerton said that it was not possible for this Conference to make detailed arrangements for the improvement of indexing and abstracting services, but it was quite clear from the discussion that there was general agreement that there was a job to be done. He therefore suggested that the Conference should invite the Royal Society to call a conference, representative of those bodies which were responsible for library and abstracting services, to thrash out what should be done, having particular regard to the cost, so that a good case could be made for the obtaining of the funds needed.

He suggested that such a conference should also consider the valuable suggestions made by Professor Bernal, as they might lead to some economies.

He mentioned also that one field of documentation had not been mentioned which was of great importance to the scientific worker, viz. the maintenance of such standard reference books as Landolt and Börnstein, Beilstein, Gmelin, etc.

Sir Lewis Fermor

Sir Lewis Fermor said that in his contributed note he had described the position in India for the dissemination of scientific information under two headings (1) for the benefit of scientists and (2) for the benefit of the general public.

The discussion this morning was concentrated on the former of these and particularly on the preparation of abstracts. In India the task of preparing abstracts had been undertaken by the National Institute of Sciences of

India. The publication was called *Indian Science Abstracts*, and wasi ssued as an annual volume. Its scope was all scientific papers published in India, and also papers about scientific matters in India published abroad. Authors were invited to submit their own abstracts, which were, of course, subject to the Editor's scrutiny. Where authors failed the duty was undertaken by the staff of the National Institute. The entry of Calcutta into the war zone and shortage of funds had caused a temporary cessation of this publication. But the Government of India had come to the rescue and publication would be resumed.

If the Dominions each produced similar publications, e.g. *Canadian Science Abstracts*, *Australian Science Abstracts*, etc., all the material would be provided for a central compilation if desired.

Dr Alexander King

I had hoped this morning to discuss further types of scientific information services which have not so far been mentioned, but which play an important part in bringing to the scientific worker the precise information which he requires, namely, the government scientific liaison offices overseas and the various organizations set up in some of the Dominions, particularly in Canada, for the dissemination of scientific information to industry. Since, however, the meeting has so far been restricted to documentation, I feel that we should adhere strictly to this aspect of the subject in order that it may have full discussion.

I should like to support Professor Bernal's idea to publish scientific papers in the form of reprints rather than as journals as at present. I speak in this connexion as a user of scientific information. In the normal course I receive a number of scientific journals from the publishing societies, but each of these contains only a small proportion of papers on my own subject. It would be much more convenient to receive these earlier and as reprints, and likewise to obtain copies of papers on similar subjects issued by other bodies in Great Britain, the Dominions and overseas. It is not as if one could profitably read the papers in the present journals which are outside one's own subject because, with increasing specialization, these are too detailed to mean very much without particular study.

I do not think that a change to a system such as Professor Bernal suggests should, in practice, prove very difficult, because the publishing societies would, as now, be the bodies responsible for attracting the papers and for their refereeing and editing. In this way all difficulties of local or national prestige could be avoided. I feel that special study should be given to this problem at an early date, and that the Dominions should be included in these conversations, although when we initially envisage a scheme for the British Commonwealth, early extension to the English-speaking world and eventually on a truly international scale, should be regarded as our ultimate aim.

In the matter of abstracting too, I feel that it would be useful and economical to invite Dominion participation immediately. It would not be difficult to arrange for each Dominion to undertake the abstracting of journals in its own area and to send these to the existing abstracting bodies in Great Britain for inclusion in the existing abstracting journals. This would mean the inclusion of additional matter in the abstracts and should

also greatly speed up the time required for the publication of abstracts of Dominion papers.

A further necessity is, I think, the preparation of general reports on particular fields to enable scientists to gain a familiarity with the main developments in subjects on which they are not specialists. Such reviews would of course be different in aim and content from the annual reports at present published, which prove so useful to specialist workers.

MEMORANDUM ON THE DISSEMINATION OF SCIENTIFIC AND TECHNICAL INFORMATION TO INDUSTRY IN THE UNITED KINGDOM AND THE BRITISH COMMONWEALTH

By Dr B. J. A. Bard

(Secretary of the Industrial Research Committee of the Federation of British Industries, and Head of the F.B.I. Industrial Research Secretariat)

1. The objectives of those engaged in pure scientific research are the creation of new and the consolidation of existing knowledge, but so far as industry is concerned, knowledge to be of value must be applied. Knowledge gained by scientific research may appear to be remote from existing industrial practice, or far in advance of the requirements of the time ; it may on the other hand be obviously of direct or immediate practical value to industry. Frequently intelligence and ingenuity are required to detect the application which may turn out to be unexpected and unrelated to the objective or field of the initial research. It is therefore of great importance that scientists present their results as a balanced picture to include all the relevant information and reasoning lucidly expressed so as to be capable of being followed by the instructed practical man in industry. Industry itself provides the most important means whereby the benefits of science are brought to the community ; its development and prosperity demand a constant striving to improve the quality and variety of its products, to increase output, to reduce production costs, and to improve working conditions. The attainment of any one of these is progress, and is dependent on the technical staff, who must be in possession of the new knowledge on which the advance is based. It may therefore fairly be claimed that an ample and well regulated circulation of information is very necessary to technical progress in industry, and depends for its life blood on a rapid diffusion of knowledge. The question of the machinery whereby such new knowledge is assembled, published and disseminated to those interested or whom it may concern, absorbed by them and then integrated and digested with existing knowledge and technical material, is taken very much for granted. In fact this process does not occur of itself. It requires to be carefully organized at each stage. So far as industry is concerned, each separate unit, if in the long run it is to survive, and enhance, or even maintain its competitive position, must make its own arrangements for the assembly and digestion of new knowledge. Furthermore each progressive industry has to be on the alert to ensure that information, from whatever source it may arise, that may concern and be of value even to a proportion of the individual units comprising the industry is recorded and brought to the notice of those units ; in other words an information service is required for each industry as a whole. This is generally provided through an industry's research association where it exists.

2. New scientific knowledge arises as a result of research carried out in laboratories, on a field site or in the works, or indeed wherever appropriate, to investigate material phenomena, either fundamentally or as specific problems with a definite objective. The knowledge gained is reported somewhere in a statement recording the factual data obtained, the general conclusions reached, and the implication of the results. This report may be published to the world through one of the recognized channels, or may be forwarded direct to those who occasioned the investigation. In a limited number of cases such knowledge may be kept secret as part of a secret process. The sum total of published material is now very large, and continues to grow at a rapid pace. Almost all fundamental research results are published in one or other of the very large number of scientific journals, and much of the applied research too reaches the light of day through various publications including patent specifications, trade and technical press and those of the professional and technical institutions. It will not be forgotten that under existing patent law the doctrine of 'publication' precludes disclosed information from being patented. In the course of the 1939–1945 war a very considerable amount of information both scientific and technical has been collected in the service and production ministries, and the Government have therefore a direct interest in this subject of the dissemination of information to industry, especially now that they have assembled so much technical and scientific information regarding German controlled industries as a result of the recent intelligence missions to the Continent.

3. It would be wrong to assume that the industrial unit must rely entirely on research results from outside sources or from the concern's own research department where it possesses one—although these are the primary sources of information. Within every industrial establishment vast quantities of working data accumulate in the form of operating, production, and performance reports ('know how' as it is termed), flow sheets, costs, designs, sales and market statistics, these include many items of permanent value, and to the extent that they are assembled, analysed, and synthesized into organized knowledge, they become complementary to laboratory researches as a basis for industrial advance. Day to day improvements in industry are in fact largely dependent upon the automatic application of this process.

4. The dividing line between 'scientific information' and 'technical information' is a fine one, the difference between them being that the former includes the results of scientific research apart from any necessary connexion with an industrial or production objective, whilst the latter covers empirical facts related to or connected in some way with industrial materials, processes, plant or products, which are the result of applied knowledge, or maybe of practical experience without a known scientific basis. For the effective conversion of research results into industrial production there must be harmonious co-ordination between the two. Even if the new knowledge to be applied arises within an industrial concern itself, there are several stages, often intricate, between the completion of the research and the development of works scale production. If the new knowledge emanates from external sources or requires to be co-ordinated (as it generally does) with existing technical experience, the chain between

its original dissemination and final application may be both long and complicated. Each link in the chain may involve the impact of the information upon a fresh mind as it is supplied, absorbed and re-emitted. The accuracy and efficiency of its original transmission is therefore of first importance. As it is rare for the dissemination to proceed without a summary or abstract form being employed at some stage, special care and skill is required to be certain that no distortion or material omission occurs, which may diminish or even nullify its value to those further along the chain, or may cause genuine seekers for information to overlook the full significance of the results.

Industry is catered for in this respect by a considerable number of government, official, public and private information and abstracting and library services which form vital links in the dissemination of information within their own field of interest ; some operate in a more general way and some restrict themselves to a particular branch of science or technical aspect of industry. Some issue regular reports and others hold themselves available to answer specific inquiries from information that they have collected or can obtain.

Within an industrial concern whose business it is to exploit science in the pursuit of economic ends, the relationship between the directive and executive sections on the one hand, and those whose responsibility it is to seek out and obtain information (referred to as ' the information department ') on the other, is of prime importance in order to ensure that once information reaches the concern it can be exploited to the full.

Two situations broadly differing in both their scope and problems must be recognized. The first is part of the day to day activities of the information department of any progressive concern. It covers the steady absorption, filing, indexing, and correlation of information reaching it as current publications, reports, abstracts, patents and non-published reports and correspondence. The normal procedure of the information department should also include providing access to current literature, including patents, obtaining translations, ' documentation ' of all material information, and keeping all sections of the concern fully aware of new developments that may affect their respective activities. In this first case, with proper organization, the necessary information is received automatically. In the second situation, however, it has to be sought out. This second situation arises from time to time when special information is required, often urgently, or at a moment of crisis, when trouble arises, or at the development stage of a new project or before a new process, product or raw material is to be introduced in the works, or when a research investigation reaches a critical stage. This may involve searches and surveys within fields remote from those which normally interest the company, and may include both information newly appearing and that which has been published in the past.

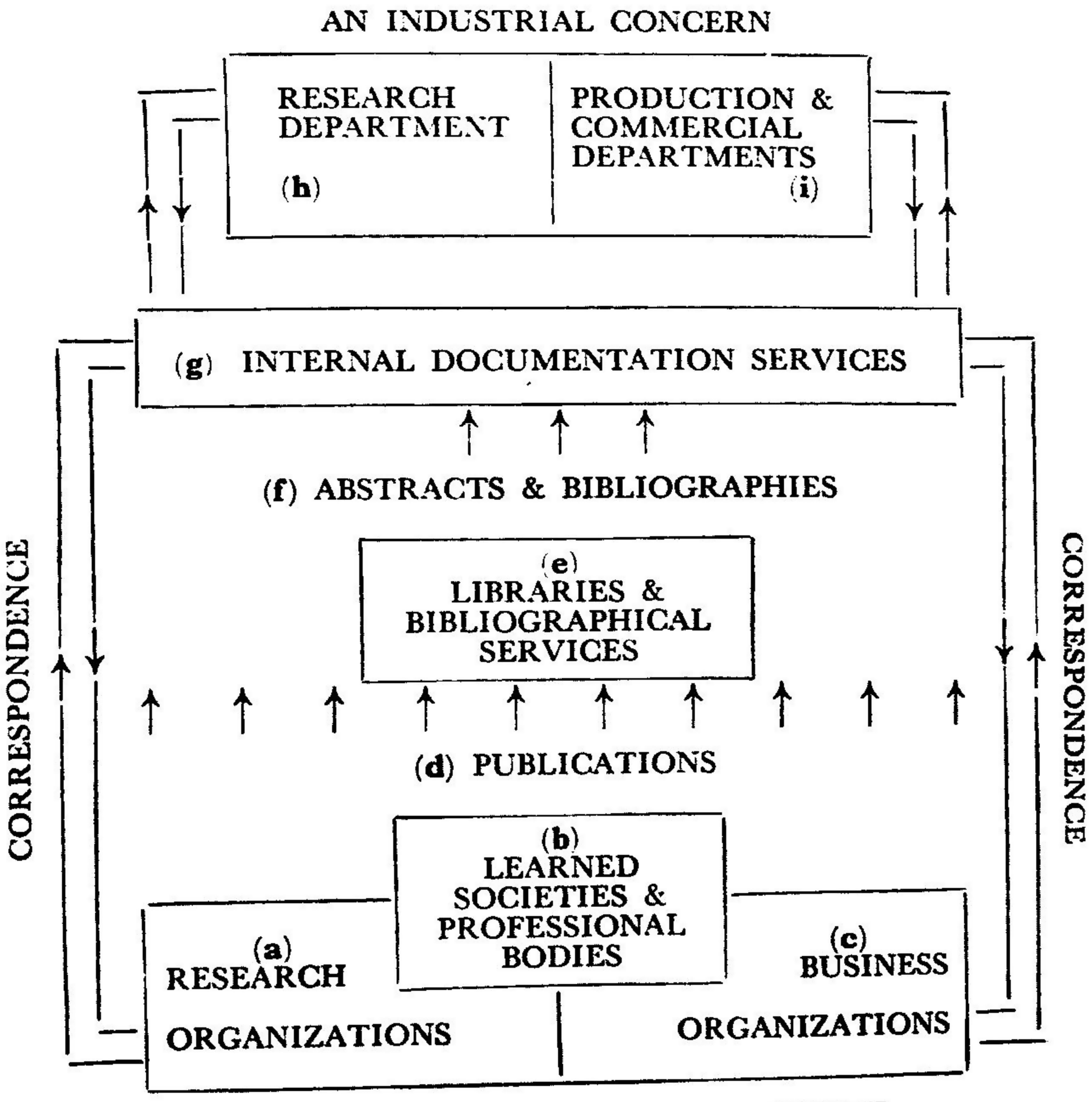
It is therefore very necessary that in the first place lists or records of authoritative references are available so that any seeker after information may be supplied with proper evidence to decide where he should endeavour to ascertain the facts required for himself, or whether he would be better advised to enlist the services of the most suitable information service. The function of special librarianship or technical documentation, including the

organization of indices is therefore of paramount importance to ensure that there is a collective 'memory' for the firm as a whole, and that information is located and held so as to be immediately available when required.

One further point may be emphasized, and this concerns the research worker himself. If, when a problem presents itself, the worker first peruses all the information he can find on the subject he may be so impressed with the many channels explored to obtain the information that he may feel there is nothing further left to be done. It may be preferable for him first to think the problem over and to carry out a little work on his own before he endeavours to ascertain what others have done. It is not entirely unknown in the history of research for mistakes to be made—and not all published information is infallible !

5. The above ideas on the flow of information are shown here in diagrammatic form (kindly prepared by the Central Registry of I.C.I. Ltd.) :

Information flow sheet



(a) ORIGINATING SOURCES OF INFORMATION

These include research laboratories, research associations, D.S.I.R. stations, government laboratories, universities, technical colleges, testing and consulting bodies, throughout the Commonwealth and Empire, as well as in foreign countries.

(b) LEARNED SOCIETIES AND PROFESSIONAL BODIES

These exist in Great Britain in considerable number. One of their main functions is to collate, digest, and enrich knowledge. (They are listed in the official Year Book of the Scientific and Learned Societies of Great Britain.)

(c) BUSINESS ORGANIZATIONS

Include government departments and committees, public institutions, trade associations, F.B.I., and such organizations as the Manchester Joint Research Council.

(d) PUBLICATIONS

Include patent specifications and abstracts, reports from originating sources, abstracts and journals from the learned societies and professional bodies, technical and trade journals, books.

(e) LIBRARIES AND BIBLIOGRAPHICAL SERVICES

Science Museum Library, Patent Office, National Central Library Organization, Association of Special Libraries and Information Bureaux (A.S.L.I.B.) and various private and semi-public organizations covering specialized fields.

(f) ABSTRACTS AND BIBLIOGRAPHIES

A list of published bibliographies and abstracts is attached as an appendix (kindly provided by I.C.I. Ltd.).

(g) INTERNAL DOCUMENTATION SERVICES

Have been referred to in paragraphs 3 and 4 above. A.S.L.I.B. acts as main liaison for those referred to in paragraph 4.

(h) RESEARCH DEPARTMENTS OF INDIVIDUAL CONCERNS

A list has been compiled by the F.B.I. Industrial Research Secretariat. Many firms with research departments are included within a special section of the Todd Publications' Reference Book, *Industrial Research*, 1946 (at page 501).

(i) PRODUCTION AND COMMERCIAL DEPARTMENTS

A list is contained in the F.B.I. Register of British Manufacturers (last edition, 1939/40), now in process of being brought up to date.

6. In Great Britain no organization exists to cover comprehensively or indeed to be responsible for the whole field of scientific and technical information. Splendid work is being done by many individual but specialized bodies, who between them publish many thousands of technical and scientific publications, journals, abstracts and bibliographies every year. Often even in a restricted subject the number of articles may run into thousands in a year, including work carried out and published overseas. Although there is much co-operation and sometimes co-ordination between abstracting bodies, these are not completely correlated with one another, for on the one hand their fields of interest frequently overlap and on the other considerable tracts are inadequately covered and some left uncharted altogether. Moreover much information although available is not readily accessible, and there are far too many places where valuable work may be published and yet only reach a small number of readers, none of whom may be sufficiently equipped to assess its value, specially if the journal is of limited circulation. There is far too great a possibility of published work being ' lost ' so far as the main body of science, and those in industry to whom it may be of value, are concerned. There would appear therefore to be scope for improvement and rationalization in this sphere.

Furthermore there is no recognized channel for putting inquiriers in touch speedily with the organization or service that can best help them, although the D.S.I.R. has recently initiated an information department to cover the activities of the various D.S.I.R. establishments. In U.S.A. the Technical Advisory Service established during the war is continuing into the peace with the ambitious plan of evolving a world programme for the universal interchange of technical information. It is also understood that the U.S.A. Department of Commerce is establishing an office of ' Technical Service.' It is not suggested that a super abstracting organization is required in Great Britain ; though there may be scope for some further kind of machinery to put inquirers in touch with the service that can best help them and to link up with the appropriate organizations in the various constituent members of the British Commonwealth, whose problems are discussed generally in the next paragraph.

7. Industry in the British Commonwealth

The special problems that confront industry in the Commonwealth and Empire in no way limit the above general analysis, although obviously there are many differences of aspect and emphasis. There is a higher percentage of small industrial concerns, proportionately smaller numbers of scientists engaged in industry, reduced accessibility of information from the originating centres (and therefore greater dependence of industrial concerns on the official information services provided by the government authority) in the Commonwealth as compared with Great Britain. On the other hand many of the industrial concerns within the Commonwealth and Empire have close business ties with British firms, and can place themselves in a no less advantageous position than their associates in Great Britain. With the relatively greater dominance of the official organizations there is far greater opportunity for the results of research within a particular member of the Commonwealth to be adequately disseminated within its boundaries.

To enable scientific and technical information throughout the Empire and Commonwealth to be effectively disseminated, any machinery set up for this purpose in Great Britain should maintain close links on a two-way basis with the various Empire and Commonwealth official bodies and would obviously keep in touch with the various scientific liaison offices of the Dominions in London and with the British Commonwealth Scientific office itself (at present in Washington, U.S.A.). The strengthening of the Colonial Research Committee and the Colonial Products Research Council to provide adequate liaison would enable the Colonial Office to play its full part.

Such a chain linking up sources and users of scientific and technical information throughout the Commonwealth will nevertheless not be stronger than its weakest link. There is need therefore to emphasize once more the responsibility which falls on the industrial units to provide their own domestic arrangements in the shape of an information department to absorb the information relevant to their activities that can be acquired from the originating and abstracting sources. How this is best to be done with the limited number of scientists at present available is a separate problem.

8. Information services specially applicable to the Commonwealth and Empire

(a) *Dominions and India*

Canada	The National Research Council of Canada The Alberta Research Council British Columbia Research Council Canadian Manufacturers' Association
Australia	Council for Scientific and Industrial Research
New Zealand	Department of Scientific and Industrial Research Manufacturers' Research Committee
South Africa	Council of Scientific and Industrial Research South African Federated Chamber of Industries
India	Directorate of Scientific and Industrial Research All India Manufacturers' Association
Eire	Industrial Research Council of Eire

(b) *Colonies*

Apart from the East African Industrial Research Board and Southern Rhodesia, which possesses an Industrial Development Commission there would not appear to be a separate service in any individual colony. Service is to a certain extent centralized through the Colonial Research Committee and the Colonial Products Research Council. The work of the former is to advise the Secretary of State on the expenditure of sums provided for research and to assist in the co-ordination of the whole range of research

in colonial studies. That of the latter is to review the field of Colonial production and to advise what Colonial raw materials are likely to be of value to the manufacture of intermediate and other products required by industry, to initiate and supervise researches on such products, and generally to consider how by the application of research greater use can be made of them.

(c) *Imperial Institute*

Collects and disseminates technical and scientific information bearing upon the raw materials of the British Empire and the processes and products of the Empire's industries and their markets.

British Commonwealth Scientific Office

Has been responsible for maintaining the exchange of scientific and technical information with U.S.A. and Canada. Future organization and operations are now under consideration.

(d) *Whitehall*

D.S.I.R., Ministry of Food, Minlistry of Supply, Colonial Office, Patent Office and Ministry of Works. All these government departments publish scientific and technical information relevant to their respective activities.

The Secretariat wishes to express grateful acknowledgment to Dr J. E. Holmstrom, Central Registry, I.C.I. Ltd., for information and advice generously provided in connexion with the preparation of this memorandum, and for the appended list of abstracts and bibliographies adapted from his book *Records and Research in Engineering and Industrial Science* (Chapman & Hall. Second edition now printing).

APPENDIX

(See paragraph 5f)

ABSTRACTS AND BIBLIOGRAPHIES RELATED TO INDUSTRY AND ENGINEERING

* Also the subject matter of one or more sections of *British Chemical Abstracts B.*

† Denotes publication interrupted by the war

Place of publication is London except where otherwise mentioned above.

subject	title or description	frequency of issue
AERONAUTICS .	*Index Aeronauticus* (Ministry of Supply)	monthly
	In *Journal of the Royal Aeronautical Society*	monthly
ATMOSPHERIC POLLUTION	*Atmospheric Pollution Abstracts* (D.S.I.R.)	2 yearly
*BUILDING . .	*Building Science Abstracts* (D.S.I.R.)	monthly
	In *Architects Journal* (Abstract Section)	weekly
*CERAMICS . .	*Ceramic Abstracts* (Easton, Pa.)	monthly
CHEMISTRY . .	*British Abstracts*	
	AI. GENERAL, PHYSICAL AND INORGANIC CHEMISTRY	monthly
	AII. ORGANIC CHEMISTRY	monthly
	AIII. PHYSIOLOGY, BIOCHEMISTRY, ANATOMY	monthly
	BI. GENERAL AND INDUSTRIAL INORGANIC CHEMISTRY, INCLUDING METALLURGY	monthly
	I. Chemical Engineering, Plant, Machinery	
	II. Fuel, Gas, Tar, Mineral Oils	
	III. Acids, Alkalis, Salts, Non-Metallic elements	
	IV. Glass, Ceramics	
	V. Building and Road-making Materials	
	VI. Metals, Metallurgy, including Electro-metallurgy	
	VII. Explosives, Matches	

subject	title or description	frequency of issue
CHEMISTRY—*contd.*	BII. INDUSTRIAL ORGANIC CHEMISTRY	monthly
	I. Organic Intermediates	
	II. Dyestuffs	
	III. Fibres, Textiles, Cellulose, Paper	
	IV. Bleaching, Dyeing, Printing, Finishing	
	V. Fats, Oils, Detergents	
	VI. Plastics, Resins, Adhesives, Paints Coating Compositions	
	VII. Rubber	
	VIII. Tanning Materials, Leather, Glue	
	IX. Photographic Materials and Processes	
	BIII. AGRICULTURE, FOODS, SANITATION	monthly
	I. Agriculture	
	II. Sugars, Starches, Gums	
	III. Fermentation Industries	
	IV. Food	
	V. Pharmaceutical Substances, Cosmetics, Essential Oils	
	VI. Sanitation, water	
	C. ANALYSIS AND LABORATORY APPARATUS	quarterly
	Chemical Abstracts (New York)	fortnightly
	Du Ponts' *Bulletin of Current Journal Articles*	weekly
*CONCRETE . .	In *Journal of the American Concrete Institute*	monthly
*DYEING . .	In *Journal of the Society of Dyers and Colourists*	monthly
*ELECTROPLATING .	In *Review of American Electroplaters' Association*	monthly
ENGINEERING—		
ALL BRANCHES .	Lists of contents in current numbers of certain journals such as *The Engineer* are so printed that each item is a complete reference, including name of journal and date	weekly
	Engineering Index (New York)	Yearly (in book form)
	Engineering Index Service (New York)	weekly
AERODROME .	*Aerodrome Abstracts* (D.S.I.R.)	(cards)

subject	title or description	frequency of issue
ENGINEERING—*contd.*		
AUTOMOBILE .	In *Journal of the Institute of Automobile Engineers*	monthly
	In *Motor Industry Research Association Abstracts*	monthly
BRIDGE AND STRUCTURAL	*Bulletin of the International Association of Bridge and Structural Engineers* (Zurich)	monthly †
CIVIL . .	Part of *Engineering Index* reprinted in *Civil Engineering* (New York)	monthly
	Engineering Abstracts, 1. Engineering construction	monthly †
ELECTRICAL .	*Science Abstracts, B*	monthly
MARINE AND SHIPBUILDING	*Engineering Abstracts*, 2. Mechanical Engineering ; 3. Shipbuilding and Marine Engineering	monthly
MECHANICAL AND ELECTRICAL	*Technical New Bulletin* of Metrovick Ltd.	weekly
MINING . .	*Engineering Abstracts*, 4. Mining Engineering	monthly
PRODUCTION .	In *Journal of the Institute of Production Engineers*	monthly
EXPERIMENT TANK WORK	Science Library Current Reference Lists	as necessary
*FIBRES . .	National and Synthetic Fibres Abstract Service (Mark & Proskauer, New York)	
*FOOD . . .	*Index to Literature of Food Investigation* (D.S.I.R.)	2 yearly
GEOPHYSICS, APPLIED	Science Library Current Reference Lists	as necessary
*GLASS . .	In *Journal of the Institute of Glass Technology* (Sheffield)	monthly
INDUSTRY (GENERAL)	*Industrial Arts Index* (H. W. Wilson Co., New York)	monthly (cumulative)
KINEMATOGRAPHY	In *Journal of the Society of Motion Picture Engineers* (New York)	monthly
*LEATHER . .	*Journal of the International Society of Leather Trade Chemists*	monthly
	Journal of the American Leather Trade Chemists	
	Summary of literature from the British Leather Manufacturers' Association	yearly
LIGHTING . .	In *Light and Lighting*	monthly
*LUBRICATION .	Science Library Current Reference Lists	as necessary

subject	title or description	frequency of issue
*METALLURGY—	Part of *Engineering Index* reproduced in *Metal Progress* (Cleveland, Ohio)	monthly
ALL BRANCHES .	*Metallurgical Abstracts* in *Journal of the Institute of Metals*	monthly
	In *Metals and Alloys* (New York)	monthly
FOUNDRY WORK	*Bulletin of the American Foundrymen's Association* (Chicago)	monthly
(CAST IRON) .	Abstracts from Foundry literature from the British Cast Iron Research Association	yearly
IRON AND STEEL	In *Iron, Steel and Industrial Fuel Bulletin of the Iron and Steel Institute*	monthly
LIGHT METALS .	In *Light Metals*	Fortnightly
NICKEL . .	In *Nickel Bulletin*	monthly
NON-FERROUS .	*Bulletin of the British Non-ferrous Metals Research Association*	monthly
MINERALOGY .	*Mineralogical Abstracts*	quarterly
MINING AND METALLURGY	Part of *Engineering Index* reprinted in *Bulletin of the Institute of Mining and Metallurgy* (New York)	monthly
*OILS AND COLOURS	In *Journal of the Oil and Colour Chemists' Association*	monthly
OPTICAL MECHANISMS	In *Dioptric Review*	monthly
*PACKAGING . .	*Packaging Abstracts* (Patra)	monthly
*PAINTS . .	*Review of Current Literature of the Paint, Colour and Varnish Industries*	2 monthly
PATENTS . .	British *Official Journal* (*Patents*)	weekly
	British *Abridgement of Patent Specifications*	irregularly
	U.S. Patent Office Official Gazette	weekly
*PAPER . .	In *Paper Trade Journal* (New York)	monthly
PETROLEUM . .	In *Journal of the Institute of Petroleum*	monthly
*PHOTOGRAPHY .	*Photographic Abstracts*	monthly
PHYSICS . .	*Science Abstracts A*	monthly
	Rheology Bulletin	quarterly
	In *Review of the Science Institute* (*U.S.A.*) *Abstracts of Current Literature*	monthly
PHYSICS AT N.P.L.	*Abstracts of Papers, National Physical Laboratory* (D.S.I.R.)	yearly

subject	title or description	frequency of issue
*PLASTICS AND RUBBER	In *Modern Plastics* (Easton Pa.)	
	Resins, Rubbers and Plastics Abstract Service, Resins, Rubbers & Patents Abstract Service (Mark & Proskauer, New York)	
	Abstracts of British Plastics Federation	monthly
	Summary of Current Literature of the British Rubber Manufacturers' Association (Croydon)	monthly
*PRINTING . .	*Printing Abstracts* (Patra)	monthly
RAILWAYS . .	*Bibliography of Railways* (Brussels)	monthly †
REFRIGERATION .	*International Bulletin of Information on Refrigeration* (Paris)	fortnightly †
ROADS . .	*Road Abstracts* (D.S.I.R.)	fortnightly
*RUBBER : *see* PLASTICS		
SAFETY . .	*Journal of Industrial Hygiene and Toxicology* (New York)	monthly
SCIENTIFIC INSTRUMENTS	*Abstracts from the British Scientific Instrument Research Association*	monthly
*TEXTILES—		
ALL BRANCHES .	In *Journal of the Textile Institute* (Manchester)	fortnightly
COTTON, RAYON AND SILK	*Summary of Current Literature of The British Cotton Industry Research Association* (Manchester)	monthly
LINEN . .	*Summary of Current Literature of the British Linen Industry Research Association* (Belfast)	monthly
WOOL . .	*Wool Digest* (International Wool Secretariat)	fortnightly
*WATER POLLUTION	*Summary of Current Literature on British Water Pollution* (D.S.I.R.)	monthly
WATERWAYS .	*Bibliographical Notes on Rivers, Canals and Ports* (Brussels)	5 yearly
WELDING . .	In *Welding Journal* (New York)	monthly
WIRELESS . .	Radio Abstracts (D.S.I.R.) in *Wireless Engineer*	weekly

THE DISSEMINATION OF SCIENTIFIC INFORMATION AMONG SCIENTISTS

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REVIEW OF INFORMATION SERVICES

By Professor R. S. Hutton

INTRODUCTION

The scope of this division of the Conference is very wide, for it embraces the collection and distribution of scientific and technical information. It should therefore include consideration of the problems of assembling as complete reviews as possible, of providing a speedy service, and of presentation in a variety of forms to satisfy specific needs.

This paper is an attempt to supplement the contributions sent in by others and in particular to examine the basic requirements of the collection and distribution of such information, to draw attention to the growing difficulties facing these services, and to indicate some proposals which have been made for improvement.

If the Conference can agree that greatly improved information services are urgently needed for facilitating the tasks of those engaged in science and technology, it is hoped that some action will be recommended to assure the preparation of a plan by an unbiased committee of scientific, technical and bibliographical experts.

If the scale of operations required for a satisfactory solution of the problem is found to transcend the resources of existing academic or technical societies, the plan may have to be directed towards securing national or empire financial support or even recommending as a government service.

THE ROOT OF THE PROBLEM

According to the last edition of the World List there existed pre-war some 36,000 periodicals devoted to scientific subjects,* but so far as is

* The 'Union Catalogue of Periodicals in University Libraries in the British Isles' (National Central Library, 1937) lists a further 25,000 periodicals not covered by the 'World List,' some of which, on economic and allied subjects, also concern those engaged in applied science.

known, no country has attempted to assemble or to make a systematic review of more than a small fraction of these.

Dr Bradford and his colleagues at the Science Library, London, have shown that in a selected grade of 15,000 of these journals, an average of three-quarters of a million individual scientific contributions appeared each year, and that only one-third of these contributions are referred to in any one of the 300 leading journals providing abstracts or indexes.[1]

Obviously, if an efficient and comprehensive information service is the goal, it is desirable to inquire if the 20,000 remaining journals can be safely ignored. Steps must also be taken to secure that all worth-while scientific articles are abstracted or at least indexed in their proper abstract journal. Without further evidence it would appear to be highly inefficient to limit the abstracting to 33 per cent of the articles appearing in 43 per cent of the available periodicals.

Further, one must take into account the great increase in scientific research since the beginning of the century, and its prospective even more rapid advance, all of which as a rule results in publications.

Sufficient statistical evidence is available to illustrate these trends.*

This flood of available literature has long since overflowed the capacity to assemble and examine of any individual scientist or even of any scientific society.

As in other aspects of scientific work, the solution for the individual may lie mainly in the better organization of team work and the division of labour, so that the original research worker has suitable access to information and secretarial assistants, who in many cases are just as necessary to him as laboratory assistants and technicians. The solution for the scientific world may depend on the establishment of new and large-scale services, but this question will be dealt with in the later sections of this paper.

Even if they are aware of the vast scale of scientific literature, many scientists are unconvinced of the importance of providing for its thorough review. No doubt most of the sceptics base their views on the fact that too much reading may interfere seriously with the time or even the capacity for original experimental or theoretical work. Others point out that duplication of research, the prior publication of which is overlooked, may not really be so disadvantageous. However true this may be in some cases, there are many examples of the serious consequences which have resulted from inefficient information services.[2] Particularly in the application of research to industrial and other objectives, the incomplete review of existing knowledge may lead to serious financial losses, either by missing chances which are taken up by other, perhaps foreign, competitors or by spending large sums on repetition of research for knowledge already available in the literature.

Apart from the difficulties caused by the gigantic scale of the literature to be surveyed there are other factors in the problem. Some of these will be dealt with later, but outstanding is the time-factor in the supply of indexed references and abstracts, since many nowadays request an up-to-date weekly or monthly service. The fact that this Conference is concerned with distribution throughout the Empire also emphasizes the importance

[1] These numbers indicate references given at the end of the paper (p. 697).

* See Appendix A at the end of the paper.

of improving and applying methods of documentary reproduction by microfilm and other photographic processes and the necessity of building up in suitable Empire centres a larger selection of scientific books and periodicals than exist at present.

SOME PAST SUCCESSES AND FAILURES

The Royal Society Catalogue of Scientific Papers, 1800–1900 inclusive, published in nineteen large quarto volumes, gives an excellent author catalogue covering the field of pure science. This was supplemented in only a few branches of science (mathematics, mechanics and physics) by subject indexes. As a library reference book this publication has permanent value, but it should be noted that it did not attempt to provide a prompt index of current science. In fact the first volume appeared in 1867 and the last in 1925.

The World List of Scientific Periodicals. One of the major achievements of the Conjoint Board of Scientific Societies * was this directory, which in its second edition published in 1934 listed 36,000 scientific periodicals and indicated which of them could be found in 187 libraries in the United Kingdom. The names of Sir Sidney Harmer and Sir Peter Chalmers Mitchell will always be remembered for their pioneering interest in this venture, the success of which depended a great deal on Government support, since the British Museum staff undertook much of the heavy editorial work.

The value of the list has been two-fold, in exposing the existence of many hitherto unknown journals, and in providing a guide to the location of the rarer periodicals.

The indirect effects have also been important. Both in the United Kingdom and in other countries, by checking up with this list, it has been possible to discover gaps and supplement national resources. The revelation that such a vast number of journals exist has made libraries, hitherto proud in their possession of a hundred or so periodicals, more willing to enter into reciprocal interchange with others.

International Catalogue of Scientific Literature. To consider the possibility of extending the cataloguing of scientific literature into the twentieth century an International Conference was convened by the Royal Society in 1896. Plans were worked out for starting an author and subject index to the world's literature in pure science from 1901 onwards by international co-operation. Thirty regional bureaux were established in individual countries to collect the material according to carefully prescribed plans. The Central Bureau was established in London to co-ordinate and edit

* In 1916 the Royal Society invited the leading scientific and technical societies in the United Kingdom to co-operate with it in dealing with a number of matters in which they were mutually interested. This Conjoint Board which was supported by over fifty scientific and technical societies, unfortunately was wound up in 1923. Although it has several valuable achievements to its credit, it failed to secure adequate financial support, the contributions averaging little more than £10 for each society. Possibly its failure was due to starting before the time was ripe, for in recent years many problems have arisen which call for handling by the co-operation of all such societies.

the individual entries. The leading part was taken by the Royal Society. which agreed to act as publishers and to advance the capital required. The field of science was divided into seventeen branches, and fourteen annual issues were published for each section covering the period 1901–1914.

The financial and other difficulties were greatly enhanced by the upheaval of World War I, and the Royal Society had ultimately to withdraw its support in 1923, having incurred very much heavier expenditure than it anticipated and at that time having a debit balance of about £12,000. The failure of this enterprise, apart from these financial difficulties, was ascribed to the lack of interest shown in the publication by those for whom it was originally planned.

The Editorial Committees put an immense amount of constructive work into this enterprise, and the Conjoint Board Committee, which held an inquiry into the possibility of improving this publication, thoroughly analysed the causes of its limitations and in 1918 put forward constructive proposals for its future.

Amongst other recommendations the Committee urged that the literature should continue to be catalogued under subjects as well as under authors. Applied science should be catalogued as well as pure science. That it was a fundamental necessity to catalogue the literature published by all nations, but to avoid delay and the inevitable difficulties of co-ordinating international contributions, from some thirty regional bureaux, the general catalogue should be prepared by a single country.

Although the alternative of a close co-operation between the leading government sponsored libraries, such as the British Museum, the Science Library and the Patent Office, and a few of the leading society libraries was considered, the Committee favoured the foundation of a central indexing institution in or near London where all the material required to be catalogued should be assembled and permanently preserved.

It was also recommended that the formation and maintenance of this institution should be undertaken by the nation.

Co-operation with the individual scientific and technical societies was envisaged, so that these societies could deal with the references collected by the central institution in accordance with their individual needs.

It is almost certain that most of these views of the Conjoint Board Committee, expressed twenty-eight years ago, would be endorsed by many at the present time who have devoted thought and attention to this subject ; although at that period the Royal Society, failing to secure adequate international support, decided that it could not sponsor the scheme proposed.

There were, of course, outside criticisms at that time of the International Catalogue. Some complained that the co-operation and advice of professional librarians might have helped to produce a catalogue which would have commanded wider appreciation and use and which could have been simplified and made more economical in cost. Others felt that the delayed publication of annual volumes limited its use and that a really prompt service both in index and abstract form was required.

The advantages and disadvantages of establishing such a central collection of scientific literature, and of linking up its indexing service with the scientific and technical societies and others publishing abstracts or utilizing

references would need to be carefully considered in any revival of such schemes.*

The aim of surveying a much higher proportion of available literature by some central institution and thereby drawing the attention of the abstracting agencies to the existence of matter occurring in journals outside their normal review, should certainly be kept prominently in view.

On the question of expense, perhaps to-day the scientific and technical world would look at this problem very differently from those concerned with it twenty-five years or so ago. Scientific research is nowadays carried out on a much larger scale and has larger funds at its disposal. It is also beginning to appreciate and apply some of the experience of the business world. Consequently an adequate percentage provision for 'overhead' expenditure for such information services should not be so difficult to obtain and should go a long way to provide the necessary funds for well-planned abstracting and indexing services.

THE PRESENT MAKESHIFT SYSTEM

The termination of the International Catalogue after the 1914 issues and its omission of applied science publications place all who require to make literature surveys in difficulties which greatly increase as the years pass, without any substitute being provided. In default of any comprehensive index for the whole of science it is necessary to depend on individual abstracting or indexing publications. Not only do these intentionally cover only limited sections of the scientific or technical field but even the best of them are admittedly incomplete. For a given objective it might be necessary to examine quite a number of individual indexes year by year and still not find any of them include it. The *Bibliography of Current Periodical Abstracts and Indexes* in the Science Museum Library, July 1939, lists 365 such publications, but of these 186 issue less than 1,000 abstracts or references per annum and only 23 over 10,000 per annum, of which perhaps the most important are the three national Chemical Abstracts, Biological Abstracts, Zoological Record, Index Medicus, Index Veterinarius and Engineering Index.

There has certainly been a great advance both in quantity and quality of the abstracts available in recent years and, as indicated by the special contributions to this Conference, those concerned with them are trying to achieve further improvements.

Attention may be drawn to the informal Conference, convened by Sir Henry T. Tizard in July 1931 when President of Aslib, to review some of

* Since the above was written attention has been drawn to the views of the British Society for International Bibliography which, for the past eighteen years, has studied this problem from several angles, and for which society much of the work of Dr Bradford and his colleagues, referred to elsewhere, was undertaken. The B.S.I.B. considers that the adoption of the Universal Decimal Classification and the co-operation of existing abstracting agencies, if fully applied, would form the most economical and satisfactory solution. Centralization, at any rate for the initial stages of indexing, would, in the opinion of others, greatly speed up the service and avoid the difficulties which the International Catalogue experienced so acutely, due to some of the co-operating agencies being so much less efficient than others.

these problems, particularly those concerned with abstracting foreign literature. The programme issued for consideration by this Conference was the following :—

(i) Methods for securing comprehensive abstracts from international sources.
(ii) Limitations of individual field and advantages or disadvantages of over-lapping.
(iii) Relative advantage of ' critical ' and ' analytical ' abstracts.
(iv) What are the best methods of dealing with foreign publications ?
e.g. : by the same staff as deal with English abstracts
by correspondents in foreign countries
by co-operation with foreign societies.
(v) Is there any need for special treatment of some foreign publications ?—e.g. Russian, Japanese.
(vi) Relative merits of a small permanent abstracting staff and a panel of part-time abstractors or other personnel arrangements.
(vii) Guide and rules to abstractors. What is the experience of different societies ?
(viii) The desirability or otherwise of some sort of uniformity in the form of the abstracts.
(ix) A consideration of methods of classifying and indexing abstracts.
(x) The preparation of annual and decennial indexes.
(xi) ' Time Factor.' How important is the prompt publication of abstracts ?
(xii) Economics of the preparation and publication of abstracts. Possibilities of mutual help by pooling of experience.

Some forty abstracting agencies were represented at that Conference and a committee was appointed to follow up the inquiry. To a questionnaire asking for details of their individual practice replies were received from about fifty societies, etc., in the United Kingdom, including nearly all the important bodies. It may be useful to quote some of the results of this inquiry. ' Mutual assistance without interference ' seems to have been generally acceptable as a goal, indicating the inclination to preserve vested interests. The survey of the literature was sometimes limited by the available budget and the majority replied that they had no effective means of abstracting papers in the less well-known languages (Russian, Japanese, Polish, Czech, Hungarian, etc.) and the majority did not appear to make any exhaustive survey of foreign literature in this field.

The conclusion of the committee was that overlapping in publication may be unavoidable, but that overlapping in preparation might be almost entirely eliminated by suitable collaboration and editing.

Photostating and other reproduction facilities appeared to be rather limited. The replies emphasized that at any rate industrialists and research associations considered that the tempo of abstracting publications was too low. On the question of the use of authors' precis to their papers, about half of those asked said that ' where suitable ' these were used as the basis for abstracts.

Aslib has on several other occasions stimulated the discussion of the problems of abstracting, and papers by the late Sir Frederick L. Nathan,[5]

the late Professor J. C. Philip,[6] Dr S. C. Bradford [7] and Dr G. S. Fulcher,[8] and a recent General Discussion [9] are referred to.

Dr Fulcher's paper reviewed his earlier contributions to the United States National Research Council on a rational form of 'analytical' abstracts, which gives a brief extension to the title by requisite annotations, and in many respects resemble the 'indicative' abstracts referred to in Dr Lampitt's paper. Of outstanding importance in this field are the studies of Dr S. C. Bradford, late Keeper of the Science Museum Library in London,[1] already briefly referred to, who has acknowledged assistance given to him by the late E. Lancaster-Jones and by H. T. Pledge, the present Librarian. This work represents a unique scientific research on the problems of this makeshift system.

The first part of this investigation comprised a statistical study of the number of ' good and very fair class ' articles published each year in some 15,000 journals and the number of entries in some 300 abstracting and indexing periodicals. In both cases the total number averaged approximately 750,000 per annum.

The second stage was the laborious collation of originals and abstracts, from which it resulted that only about one-third of the original papers receive notice in any of the indexing publications. In some technical subjects the proportion of neglected papers was considerably higher.

A third investigation studied the ' scatter ' of papers on given subjects throughout the whole range of scientific journals.[10] Taking Applied Geophysics and Lubrication as examples (a similar study was carried out for Electrotechnics), it was found that if periodicals containing articles on a given subject are arranged in groups in decreasing order of the number of articles they contain on the specific subject, and if these groups are divided into a nucleus of journals more specially devoted to the subject and into further groups containing the same number of articles as the nucleus, the number of journals in the different groups may be expressed as $1 : N : N^2$ where N is about 5 or 6.

Many scientists who have not yet personally experienced the results of this scatter are inclined to suggest that it is unlikely to apply to the major branches of science and technology and to be more confined to very special or newly developing sections. This is a dangerous attitude if at the same time reasonable completeness of review is desired. With the strong nationalist tendencies which sometimes prevail, or even from the influence of less cogent reasons, outstanding discoveries may well appear in the proceedings of rare State societies and/or in languages beyond the reach of a normal reviewing staff or even in some ephemeral specialist journal.[2]

Attention should also be drawn to some valuable data in a paper by the late E. Lancaster-Jones, who succeeded Dr Bradford as Keeper of the Science Library, entitled *Evaluation of Scientific and Technical Publications*,[1] which gives the results of some tests on the library holdings in the United Kingdom of periodicals in the World List and of their review in recognized abstracting periodicals.

Dr Bradford concluded from these studies that a radical change is needed and that periodical literature must be indexed in the first place by source and on a planned and all-embracing scheme rather than by subjects

as normally occurs with our present abstracting system. He envisaged therefore a clearing-house and a standard system of classification so that attention of these special interests can be drawn to publications from however wide a field they may originate.

The British Society for International Bibliography, affiliated with the Fédération Internationale de Documentation of the Hague, has published further work by Dr Bradford and others on this subject and has given special attention to the application of the Universal Decimal Classification to the production of a comprehensive index to scientific and technical literature.

This society has already induced thirty bibliographical institutions in this country to adopt the Decimal Classification for their abstracts and is co-operating with a number of continental societies who have adopted the same system.

Although this is not the place to discuss the pros and cons of the U.D.C. it is obvious that, before it starts, any indexing organization, planned to cover world-wide scientific and technical literature on the scale it now presents, must decide this crucial question of a system of classification acceptable by and suitable for its potential users. It is hoped that in making these plans full consideration will be given to the views of all who have constructive proposals to put forward, whether they be scientists, librarians, or information officers versed in the day-to-day use of large-scale bibliographies.

FUTURE NEEDS AND PROSPECTS

Several of the requirements of an improved information and abstracting service have already been referred to, such as the essentials of

(*a*) comprehensive coverage of the literature of pure and applied science,

(*b*) prompt availability of the results of the surveys,

(*c*) classification of the individual items at the point of their collection.

Before any noteworthy advance can be made many important questions must be examined and decided, amongst these (i) the adoption of the Universal Decimal Classification or of some alternative, for it is indispensable that the indexes and abstracts should be subdivided so that anyone wishing to secure a bibliography of some subject matter with which he is concerned can do so in the most efficient manner possible, (ii) the relative advantages of either (a) a central institution newly established to collect the original publications, index them (for subsequent abstracting either in the same institution or by the usual abstracting bodies), file them for reference, and perhaps in addition supply to order, photostat, microfilm or other copies for the service of individual research workers, at home or abroad, or (b) a co-operative scheme by which suitable abstracting bodies will work together along carefully prepared lines so as to cover the whole field of scientific literature, classify and interchange it by some logical system and between them issue abstracts and/or indexed references adequately reviewing the whole output of the literature of pure and applied science, (iii) the financial cost and the sources from which this can be met.

In considering the possibilities of a rapid service of literature references, attention may be drawn to the *Engineering Index* of the U.S.A. Engineering

Societies Library. The annual volumes include details of about 50,000 articles appearing in 2,000 journals published in twenty different countries. The remarkable character of this enterprise, however, is the weekly provision to subscribers of annotated index cards, in 282 classified divisions of the whole field of engineering, which may be selected either separately or in groups. By this service any individual or institution can have his attention drawn to new publications with extraordinary rapidity, and the cards obviously form the basis for a permanent bibliography. The annotations give a concise description of the articles indexed, and thus extend the details of the contents provided by the title.

The adoption of such a system extended to cover the whole field of pure and applied science is rather similar to what some have in view as a ' feeder-station ' for the individual abstracting agencies.

In emphasizing the importance of comprehensive coverage of the scientific and technical literature, this insistence must not, of course, be taken too literally. Some selection will always be necessary, for no agency could possibly undertake the indexing of every short note or item occurring in the whole range of periodical literature.

With regard to organization and financing of the improved services, again many questions need examination and decision. The following would need to be included amongst these questions :—

(*a*) The effect of the almost complete termination of the German editing and supply of reviews of scientific literature, which gives both an opportunity and an onus on the British not to leave entirely to foreign countries the replacement of what is really necessary of this lost service.

(*b*) The experience which the national libraries have had in previous bibliographical work for science should be mobilized if possible in connexion with any new scheme. The British Museum work on the World List has been referred to and, apart from expert assistance in other directions, it might be particularly helpful in reporting on the birth of new periodicals and the disappearance of others. The Science Library at South Kensington already holds the largest collection in the United Kingdom of scientific periodicals, and under successive librarians has played a leading part in this country in developing bibliographical services.

(*c*) The Imperial Agricultural Bureaux have attained a high reputation for the information services they provide and in particular for those ' informative ' abstracts which doubtless are of a type suitable for overseas requirements, and these forms of distribution need consideration as possible examples to follow in any new development. These services are dealt with in Sir David Chadwick's paper.

(*d*) The Department of Scientific Industrial Research has from its earliest days encouraged the provision of information services both in the Institutes which it controls directly and in the Research Associations. Its Headquarters Records Bureau has been of great service and the extension of the D.S.I.R. activities in these directions by the establishment of a Division for Intelligence and Publicity is welcome, especially as one of its functions will be to improve the

liaison and interchange of information with the Dominions. How far these activities of the D.S.I.R. can be further extended to undertake some or all of the new tasks ahead deserves careful consideration.

(*e*) It would be dangerous to try at this stage to estimate the financial budget which would be required to satisfy the present-day needs of information services. Some data on this aspect of the question could easily be assembled, e.g. the experience of the Royal Society in financing the International Catalogue, some of the abstracting societies have already published their costs, and Dr Bradford has given estimates based on his experience at the Science Library. It would also be advisable to seek advice from the United States of America where, apart from the *Engineering Index*, the H. W. Wilson Company of New York has introduced very efficient methods for publishing, on a large scale, indexes in a number of different fields of periodical literature and particularly in dealing with 'cumulative' indexes, issued month by month and cumulated quarterly and/or annually.

(*f*) This question of cost might also be approached from another side. All new pioneering enterprises are up against the unimaginative opposition that never before has so much been devoted to pursuing the suggested novel development. Can we afford to go on doing without a comprehensive cataloguing of scientific literature? Before answering this question it is important to realize that the situation is rapidly deteriorating as a result of the great increase in the output of scientific publications.

If it is agreed that better provision must be made, the next question is how much should be spent on supplying it.

It might be useful to review the proportion of total costs of scientific or industrial research organizations devoted to the provision of information. These percentages would no doubt vary considerably, but the higher figures, if found to be based on careful planning, might serve as a helpful target. Even if a well-organized industrial research enterprise is found to spend 25 or 33 per cent of its funds in this way it does not, of course, include what it already secures or hopes to find from outside public services. The problem here is what percentage of Government support for scientific research and education should be devoted to the provision of better information services, including the indexing and abstracting of publications, for the assistance of those who are themselves supported by Government grants directly or indirectly.

It will probably be found that we have not yet acknowledged the full importance of this side of the scientific research needs by adequate financial provision, and in any case the rapid increase of the Government grants to scientific research call for a corresponding advance in the amount devoted to such information services.

For an ideal and complete survey of outside research work, prior to starting a major investigation, even more is required than a preview of publications.

It is always possible, and sometimes even likely, that someone else has

already started, or contemplates starting, a similar enterprise and the opportunity thus occurs, if it could be recognized, for useful co-operation.

Suggestions have, in consequence, been put forward from time to time, that, for different fields of pure and applied science, some co-ordinating authority should collect and publish particulars of work in progress, researches contemplated and even of equipment and facilities available in research laboratories.[14] Obviously the release of such information must be voluntary, at any rate so far as private enterprise is concerned, but some examples of such published programmes indicate how useful and interesting they might be.[15]

This paper deals almost exclusively with the collection and distribution of information for those engaged in scientific research and education, but many of the developments envisaged might have application in the *Institute of Scientific Information* which is proposed in the paper submitted by Sir Richard Gregory's Committee to another session of this Conference.

In Mrs Moholy's Conference papers on Documentary Reproduction attention is drawn to a field of information services of growing importance and of particular interest to intercommunication of scientific publications in the Empire.

The war-time experience and success of the Aslib Microfilm Service, under Mrs Moholy's direction, and of some of the imperial microfilming organizations prove how useful such aids can be, and their revival and extension for post-war needs is certainly to be hoped for.[12]

The great importance of the rapid transfer of copies of publications and MSS. during the war introduced many to the unique advantages of microfilms, but documentary reproduction covers many other methods suitable for each individual need.

Many will realize the importance of developing the provision of such a service from a central office, as proposed in these papers, which should doubtless be associated with any organization set up to deal with indexing and abstracting.

Before such services can be fully developed it is necessary to solve the copyright question, which at present is left in such an uncertain state despite the protection the act provides for those who desire copies for private study and research.

The paper by Professor Bernal presents in brief form proposals which he has put forward elsewhere ; [13] and again emphasizes that these matters need to be considered at the present time on a really broad basis. The fact that these proposals would cause considerable changes in the practice of individual societies and periodicals should not stand in the way of their consideration and adoption. As has been repeatedly emphasized we are rapidly approaching almost a deadlock in the flood of scientific publications which are constantly growing in volume ; and unless some really efficacious methods are adopted in publishing, indexing and classifying them, we may well end up in a situation where much of our experimental and theoretical research becomes merely a blind repetition of results already achieved by our predecessors.

APPENDIX A

Some Data on the Growth of Scientific Publications

E. W. Hulme, late librarian of H.M. Patent Office, in his *Statistical Bibliography in Relation to the growth of Modern Civilization* (Grafton & Co., London, 1923), and in *Nature*, 25 July 1925, vol. 116, p. 129, reviewed the data given in the indexes of the *International Catalogue of Scientific Literature, 1901–1913* and in the *Royal Society Catalogue of Scientific Papers, 1800–1900*. These data are reasonably comparable and cover the whole of pure science, but do not include applied science. Starting with a yearly average for the period 1800–1863 of 3,097, output had increased to an annual average of 22,616 for the period 1874–1900. The yearly figures in the present century increased fairly rapidly and reached 85,519 by 1910.

Quite independently E. J. Crane, editor of the *Chemical and Engineering News* (American Chemical Society) 10 September 1944, shows that between 1909 and 1939, judging by American chemical abstracts, chemical research activity increased four-fold, the number of abstracts amounting to over 45,000 in the latter year.

These figures are indicative of the rate of growth, but the real scale of the problem is probably more correctly brought out by Dr Bradford's Science Library studies, which show that even in 15,000 journals the whole mass of literature to be indexed and reviewed amounts already to 750,000 items per annum, and for evident reasons is likely to surpass these figures in the near future.

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E. Lancaster-Jones. 'Evaluation of Scientific and Technical Periodicals,' *15th Aslib Conf. Rep.*, 1938, pp. 72–83.

[2] Pollard, A. F. C. 'The Disordered State of Bibliography and Indications of its Effect upon Scientific and Technical Progress.' *Proc. Brit. Soc. for International Bibliography*, 1942, vol. 4, pp. 41–52. In this paper Professor Pollard quotes some startling examples, including that of Mendel's original work being lost sight of for thirty-five years.
Dr A. Prins of the Dutch Patent Office has calculated that from a large collection of patent applications 65 per cent were refused and a further 31 per cent limited because the inventions were already wholly or partly known (quoted by Bradford, see [3] below).

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THE FORM AND DISTRIBUTION OF SCIENTIFIC PAPERS

By Professor J. D. BERNAL, F.R.S.

THERE can be no doubt that the growth of scientific effort in the world has made the task of proper distribution of scientific information a critical one, in that, whereas the annual increment of new knowledge in the whole field of science and in any particular field is rapidly increasing, the capacity for assimilating knowledge of each individual research worker, is absolutely limited. This situation has been much aggravated by the effects of the war both in interrupting fundamental scientific research and in disrupting the publication service of Europe and particularly of Germany. It does, however, also give an opportunity for remodelling certain features of the publications services and one which is unlikely to recur, as any change made now would be felt less than one made in more settled times.

The changes required are those which should provide for the workers in science the maximum of information relevant to their work and the minimum of irrelevant information ; that is, it should aim at efficiency and economy. This can only be done by the better organization of the production and distribution of the basic unit of scientific publication—the individual paper. This can be achieved without any interference with the autonomy and function of scientific publishing bodies, such as scientific societies, by the formation of an adequate distributing agency using modern

methods of reproduction and distribution. The basic principle is one which is already used in various technical publications and is widely practised among scientific workers, of distribution of 'separates' arranged so that they can be joined together in a variety of ways according to the needs of the recipients.

The distribution of papers and abstracts could be undertaken by a number of central distributing offices, set up jointly by scientific societies and other publishing bodies in each country. The individual paper would be sent in, accepted and edited by the scientific society as is done at present but it would be printed and distributed by the central office to individual members of societies in its own country and to corresponding distributing centres in other countries. Each member of the society would receive a number of papers, at least as large a number as he now obtains for his regular subscription, but these papers could either be obtained by a standing block order for papers in certain defined fields, or by specific request or both. Extra papers such as would be needed by libraries or institutions, would be available on higher rates of subscription. The individuality of journals would be retained, as papers published by a particular society could always be bound in volumes as at present, but scientists or libraries would be much freer in the arrangement of material. A similar scheme could be adapted for reprints and reports.

Such a scheme would fit in very well with the proposals of Dr Lampitt for abstracts, and the same body could undertake the distribution of abstracts and of papers. Just as Dr Lampitt has divided abstracts into the shorter indicative and the longer informative abstracts, so the same scientific papers might appear in two lengths ; a general paper containing the account of the research, its conclusions and discussions, which would have a wide interest, and a longer paper including experimental details and full tables of results, which would be of value to specialists working in that particular field. The first type of paper could be printed in the ordinary way and the second could be microfilmed and distributed in small numbers to interested parties.

If such a scheme could be agreed on by representatives of scientific societies of the British Commonwealth, United States and other principal scientific countries, it would offer considerable economies in publication. The actual amount of printing might be less than at present and the service to each individual scientific worker would be much more. It is suggested that the proper way to pay for such a service is to treat it as a common scientific service to be borne on the general budgets of the countries or through their subscriptions to UNESCO. At present, when the vast majority of scientists are working in directly or indirectly Government subsidized laboratories, it seems both illogical and wasteful to make them pay individually for an absolutely essential part of their work, and the taking of the burden of publication costs from the societies and individual scientific workers could only lead to the enhancement of the more purely scientific activity of both.

It is clear that a scheme of such magnitude cannot be achieved without serious and detailed consideration by competent authorities but this should include at least as many representatives of the users as of publishing bodies.

AN ABSTRACTING SERVICE

By Dr. L. H. Lampitt
(Bureau of British Abstracts)

It is not without significance that the problem of an efficient abstracting service should have exercised the minds of scientists for many years, for it is but secondary in importance to the actual publication of new discoveries. No other system of bringing to the notice of investigators the work of others can replace the publication of abstracts, which not only acts as an index but as an indication of the scope and object of the investigations being pursued the world over.

The highest development of abstracting is seen in the sciences allied to chemistry, both in the pure and applied fields, which is only to be expected since it was chemists who first realized the importance of this service. It cannot be said that abstracting is as efficient or as comprehensive in other sciences.

It is important to consider the ' type ' of synopsis of a paper which may be published as an ' Abstract.' It should be either ' indicative,' that is short and concise, giving the main points of a paper, or ' informative,' longer and more detailed. This second type is obviously of more importance where access to original literature is difficult, although possibly the introduction of the microfilm method of reproduction of original articles will in the future lessen the necessity for this type of abstract.

Previous to 1938, abstracts of the ' indicative ' type, although varying in conciseness, were published in a comprehensive form in only three countries, by the Bureau of Chemical and Physiological Abstracts (now the Bureau of Abstracts) and by Science Abstracts (dealing with physics and electrical science) in this country, by the American Chemical Society in the United States of America, and by private enterprise in Germany. The distribution of these various publications was broadly as follows. English publications to the Commonwealth and the United States with a not inconsiderable number of copies to Japan and China, but few to South America or Europe. United States publications were widely distributed. German publications had a large sale in Europe, the East and South America. Conversations lately reveal that France, Holland and Scandinavia are eager to receive British Abstracts, but unfortunately the shortage of paper has as yet prevented advantage being taken of this desire. On the other hand abstracts of the ' informative ' type were published by many specialized journals in many countries, by the Imperial Bureau of Agriculture and by other Government supported organizations.

Both in this country and in the United States there is a great wastage of effort, for the main abstracting services, now covering a very wide field of interest, overlap not only to a certain extent with each other but also with the multiplicity of smaller bodies which cater for the specialist or for relatively small groups of workers, particularly in the issue of ' informative ' abstracts.

In this country this waste of effort is to be deplored, but it can only be by the establishment of a central abstracting organization, which must be imbued with imagination and energy, that the present state of affairs can

be overcome. What are the difficulties to be surmounted? They fall essentially into two categories, personal and financial—all others are of minor importance. The personal difficulties are again two-fold, they are partly to be ascribed to the reluctance of some bodies which already have an abstracting service to lose their identity with this important work. This is a serious but not insuperable obstacle, it is however very real and the amount of goodwill and commonsense required to resolve it is considerable. Those responsible for the publication of all these sets of abstracts are sensible of the service they are rendering to the members of the groups for whom they cater; it will only be by convincing them that the formation of a central abstracting organization would render a valuable contribution to the scientific life of the country, in other words would further the development of the country itself, that they would be willing to forego the prestige and sacrifice an amount of vested interest. The experience which has been gained by the amalgamation of the purely chemical abstracting service of the Bureau with that of the Physiological Society leaves no question of the advantages to be gained by such joint work and no one would suggest that the Physiological Society had lost anything by its far-seeing attitude.

The second of the personal difficulties is one of a more practical nature and is concerned simply with reconciling 'indicative' and 'informative' abstracts. 'Indicative' abstracts should not be subject to selection, for although prepared by specialists, the abstractor should faithfully abstract that portion of the literature which comes before him to give a true indication of the scope and purpose of the published papers. 'Informative' abstracts have all been selected. In the case therefore of a central abstracting organization, the abstractor would prepare two abstracts instead of one; the first, 'indicative,' would go forward for publication in the usual way; the second would go forward to the particular sectional interest for special consideration, it might in effect have to go to two or more interests. For example, an article on the effect of cooking on the ascorbic acid content of a green vegetable might contain information of value to the chemical engineer and to the enzyme chemist—the informative abstract would therefore go before the respective sections of the main abstracting organization concerned with chemical engineering and with enzyme chemistry. It will be seen, however, that this would entail more sectionalization in order that subscribers would be enabled to obtain the cover for the portion of science in which they were particularly interested. With the greater specialization of science and with the narrowing of interest of groups of people, this seems to be the inevitable path of development.

Another factor, and one the effect of which is already being experienced, is the growing nationalistic sentiments of the world. Every country must be self-supporting, every country must have its own scientific literature, and whereas twenty years ago, all important scientific work was reported in one of three languages, English, German or French, to-day much is being written in languages but little understood outside narrow national borders. It would seem therefore that to obtain a satisfactory survey any service will need to be prepared to abstract far more papers in little understood languages, and this would appear to entail a comprehensive organization rather than a multitude of smaller ones. It may be said

that the Bureau is seeking to overcome this difficulty by establishing groups of competent abstractors in the countries of origin of the papers. This will not only solve the language problem but will tend to speed up publication of the abstracts.

There are at the moment large portions of scientific literature which are not efficiently abstracted. To quote as example two, namely medicine and agriculture. There are many journals which publish abstracts in both these fields, but there is no comprehensive survey. The aspect of these subjects which may be said to be chemical is covered, but in neither case is the subject as a whole covered. They are both very wide subjects, and would necessitate a large organization to cope with them. It cannot be denied, for example, that rural sociology or agricultural economics are not sufficiently important aspects of agriculture to merit efficient abstracting. The work of the Imperial Bureaux is most important and as a service in selected informative abstracts cannot possibly be bettered in the groups of subjects with which it deals, but it certainly does not cover the science of agriculture. Indicative abstracts are urgently required in both medicine and agriculture, aspects of science which to-day are of prime importance.

In the second category of difficulties is that of finance. Until some ten years ago, the whole of the cost of abstracting chemical subjects was borne by the members of the scientific publishing societies. To-day, by its contributions to the Chemical Council, British Industry supplies some £7,000 a year to the publications of the Chemical Society and the Society of Chemical Industry, and this year a direct grant of some £2,000 has been made to the Bureau. Were it not for the sale-income, that is, money derived from the sale to non-members of the Societies, publications of new matter and abstracts could not continue. In order to give an idea of the amount of money involved the following may be quoted. In 1944 with a circulation of some 4,000 copies the cost to the Bureau to produce 1,408 pages containing 23,119 abstracts was £14,000. It has been estimated that a sum of £10,000 per annum would be required to abstract medical literature and give a satisfactory distribution ; possibly £5,000 would be required for agriculture. These figures indicate the financial difficulty : in respect of a country practically nothing, but in respect of the scientific worker, a heavy burden. It would appear that the State should become a partner with Industry and the Scientist to finance this essential work.

To sum up, it would appear that a Central Abstracting Science Service should be developed, which should issue both indicative and informative abstracts ; that on the Council or Board of this Body should be representatives of all the major publishing societies or institutions ; that both indicative and informative abstracts should be highly sectionalized ; that the scheme should be financed jointly by the State (possibly by the members of the British Commonwealth of Nations), industry and the scientific worker.

SPECIAL LIBRARIES

By E. M. R. Ditmas
(A.S.L.I.B.)

1. SCIENTIFIC INFORMATION SERVICES—INTRODUCTION TO THE PROBLEM

Until comparatively recent times the main conception of the library was that of a depository where books and other documents could be put at the disposal of students who were able to come and consult them. In its relation to the user, the function of the library was thus mainly passive ; a good library was one which held its treasures ready for production at the call of the scholar. The initiative was expected to come from him and the librarian was primarily the provider and custodian of the documents.

This older type of library service had great merits. Vast resources have been built up by national, academic and local bodies, which form the background of the national library system and are the final resort of the serious student in all fields of knowledge. Nevertheless developments in scientific specialization and particularly in applied science have created new demands for which other types of library service are required. It is probable that no library, great or small, State-owned or in private ownership, can remain untouched by the influence of the new demands ; but within, and additional to, the traditional libraries there are now needed special libraries and information services. In these the original function of the library as a storehouse of books will be supplemented by positive activities through which information will be selected from the documents and deliberately directed where it is needed.

These developments have brought into existence a new type of worker, the Information Officer, specially trained to take a brief from the particular group of specialists whom he serves, to track the information needed in solution of particular problems and to utilize efficiently every available resource in equipment and technique for communication. He is, in fact, an intellectual liaison officer. Many are now realizing that too much specialization may defeat its own ends. On the one hand there may be waste of time because the clue that might have been found in a neighbouring field may have been overlooked ; on the other hand since the results achieved in one specialist field may have vast reactions on other and often seemingly unrelated fields, certain effects of new discoveries may not be realized until much harm has been done. Changes brought about by a disturbance of balance in one part of Nature may not necessarily declare themselves quickly nor in the same field. Exploitation of natural resources may encourage erosion ; the introduction of foreign fauna or flora may be the first step in the development of plant or animal pests. Not only must the existence of these harmful repercussions be readily detected, the knowledge needed for their elimination or control must be disseminated quickly. The specialization which is a necessary feature of present-day science must be balanced by an increasingly efficient network of communications and liaison so that whenever and whatever developments take place in one field of activity, workers in related fields may be enabled to be immediately aware of them. This is the information service problem.

No library, however large or however well organized, can now hope

to be entirely self-sufficient. Therefore the main problem before this Conference must be the creation of inter-library links so that all published and much unpublished material shall be as nearly as possible immediately available to all qualified workers wherever they are in a world-wide system.

2. THE PRESENT LIBRARY SYSTEM

The present library system—though system is too precise a word—includes the following main types of libraries :

(*a*) National and State-owned libraries : the copyright libraries ; the national libraries without copyright privileges, e.g. the Science Museum Library, Patent Office Library, etc.
Government departmental libraries, e.g. Ministry of Education Library, Ministry of Agriculture Library, Ministry of Works Libraries, Air Ministry Library, etc.
Libraries of research establishments directly controlled by Government departments, e.g. the D.S.I.R. research station libraries, armaments research library, etc.

(*b*) Imperially-supported institutions, e.g. the Imperial Institute Library, the Imperial Agricultural Bureaux, etc.

(*c*) University libraries : the larger university libraries and university college libraries.

(*d*) Local authority libraries : the greater municipal libraries with specialist departments, e.g. Manchester Public Library, Bristol City Library, etc.
The smaller municipal libraries.
The county libraries.
The libraries of technical colleges and other educational establishments.

(*e*) Professional and research institutions and learned societies, e.g. the library of the Royal Society, the Institution of Civil Engineers, the Royal Society of Medicine, the Royal Institute of British Architects, etc.

(*f*) Industrial libraries : Industrial Research Associations linked with the D.S.I.R., libraries maintained by individual firms.

(*g*) Commercial libraries : Chambers of Commerce, etc.

(*h*) Private individual libraries.

Associated with the library system are certain auxiliary services, amongst which may be noted the following :

(i) The National Central Library.
(ii) The abstracting services.
(iii) The British Society for International Bibliography.
(iv) Aslib.

Before alternatives are considered, it may be as well to indicate some of the characteristics of these various types of libraries and library services.

(*a*) *The State-owned libraries*

In their present form the copyright libraries, such as the British Museum, are essentially depositories. They ensure that at least one copy of each

British publication shall be available for consultation, but the books cannot be sent on loan. Apparatus for photographic reproduction exists, but it is slow in operation and, because of copyright restrictions, it is limited to certain classes of material. There is no national bibliographical service, and any accession lists published by those libraries are so long in production that they give no indication of current British publication.

The Patent Office Library and the Science Museum Library give specially valuable service to the community in the fields of pure and applied science; in particular the Science Museum Library supplies on loan a very great many scientific books and periodicals to universities and learned institutions and to research libraries of every type, including the industrial libraries.

Libraries attached to Government departments serve, in the main, a more limited public and vary widely in their development. Unfortunately there is a good deal of evidence that the Government does not yet realize that these libraries should be organized as integral parts of a planned system. Their importance as the necessary adjunct to national scientific and cultural development has not yet affected the Civil Service machinery by which they are maintained. The conception that the library is either a passive collection of books to be held under the watchful control of a 'keeper,' or an *ad hoc* collection of documents assembled for departmental use still dominates. The result is the very unequal development of Government libraries and information services and great variation in the degree of importance attached to the need for trained and experienced personnel.

Present conditions have their roots in the past and, as a nation, we are not library-conscious nor have the majority of people any idea of the rapidly developing need for the liaison services. Under war conditions Government departments enlarged themselves and subdivided overnight, and special library collections sprang up in widely scattered localities. A document urgently required by one section might be unnoticed in a neighbouring department; three or four groups might simultaneously investigate the same problem and harried officers chase the same unique document. Yet, because the value of a really sound system of intercommunication had not been visualized as an essential accompaniment of decentralization when this was first planned, the growth of efficient communication was too often strangled when the need became urgent.

An idea of what might be achieved is shown by the successful organization of that group of research stations and laboratories which are attached to the Department of Scientific and Industrial Research. Each member of the group concentrates on certain subjects such as Food, Fuel, Road, Building, etc., and most of them issue periodical abstracts of the world's literature in their field. There is no complete standardization of library method, but the activities of the group as a whole are co-ordinated by the central office, thus preventing overlapping and waste.

Outside this group of State-supported organizations but closely linked with them are thirty-two industrial research associations, each partially financed by the industry which it serves but also receiving a grant from the Government proportionate to the support it receives from its members. More will be said about these under (*f*).

(*b*) *Imperially-supported organizations*

The Imperial Institute maintains a very valuable service of information between this country and the Empire, covering such matters as the testing of samples, advice on markets and the preparation of produce to conform with market needs. Its two main scientific departments deal with plant and animal products and with mineral resources ; both are served by a single statistical section and by a library.

The Imperial Agricultural Bureaux, which are also financed by contributions from the Empire, comprise twelve centres each specializing in some aspect of agriculture and each aiming at covering all information in its own field wherever published. As in the case of the D.S.I.R. group, the activities of the various bureaux are co-ordinated through an Executive Council in London but there is no enforced standardization of bibliographical method. The functions of the Imperial Agricultural Bureaux are primarily those of information centres and abstracting bodies and each is situated at an experimental research station or institution specializing in its subject. Thus the Imperial Bureau of Animal Nutrition is housed at the Rowett Research Institute, Bucksburn, and the Imperial Bureau of Plant Breeding and Genetics is at the School of Agriculture of the University of Cambridge.

The bureaux libraries are not extensive, but each searches the institute library and others germane to its subject. As part of its regular duties each publishes a journal composed of abstracts of current scientific information on its subject.

Another example of an imperially-supported information centre is the Bureau of Hygiene and Tropical Diseases, housed at the London School of Hygiene and Tropical Medicine ; this Bureau acts as a clearing-house for the rapid dissemination of medical experience and research in all branches of public health and preventive medicine.

(*c*) *University libraries*

The two greatest university libraries, the Bodleian at Oxford and the Cambridge University Library, are copyright libraries. As in the case of the British Museum, these are primarily national depositories of books, and loan facilities are restricted. They perform also the invaluable function of ensuring that, at the larger academic centres, there shall be available to the scholar vast collections of books and periodicals on all subjects. Nearly all the other university and university college libraries make their books available (apart from early and rare works) to a wider public through the Joint Standing Committee on Library Co-operation and the National Central Library.

(*d*) *The local authority libraries*

For the purpose of this paper it is not necessary to enter into detailed description of the public library system of Great Britain. Mr L. M. McColvin's report, ' The Public Library System of Great Britain,' issued in 1942, both describes existing conditions in detail and sketches certain desirable developments. It is enough to mention the important part played by these libraries for all classes of the local community. The nation-wide link-up through the regional library system and the National

Central Library is referred to later. In addition it should be noted that certain of the larger city libraries serving areas with specialized industrial development contain collections of unrivalled importance in connexion with these particular industries; such libraries are those at Sheffield, Leeds, Bristol, etc.

(e) Professional and learned societies

The libraries attached to learned societies and professional institutions exist in every stage of development. Many of them constitute some of the finest collections in the country and the extent of their resources must never be overlooked in any survey of the British library system. They are, however, primarily created to serve the needs of their members and in the past most of them have tended to maintain a tradition of isolationism. A number of them are however co-operating in the inter-lending system and it should be possible to find means whereby fuller co-operation could be secured without detracting from the service which they owe to their members. In the field of architectural, building and town planning studies some considerable progress has already been made on the initiative of the Royal Institute of British Architects in promoting co-operative bibliographical and library services between the principal ministerial and professional libraries. A somewhat similar link-up of medical libraries is organized by the Royal Society of Medicine.

(f) Industrial libraries

Here there are two distinct groups. First there are the thirty-two industrial research association libraries linked with the D.S.I.R., aided by grants from the State but depending in the first instance on a proved desire of the industry in question to engage in research and in the pooling of scientific information. The names of these research associations, i.e. the Wool Industries Research Association, the British Non-Ferrous Metals Research Association, the British Rubber Manufacturers Research Association, etc., are self-explanatory. Each maintains a library and most of them also act as information bureaux for the industries concerned, with all the activities, such as abstracting, etc., implied by that term.

Secondly there are the libraries maintained by individual industrial firms. Recent years have seen an extraordinary growth in the size and importance of these, and the enormous part now played by science in industry and the modern emphasis on industrial research will continue to foster their development. They are, however, libraries created to serve the needs of the firms and do not make provision for outside research workers. Where the appropriate industrial research associations exist the private industrial libraries make contact with a system of centralized information services, and there is a certain amount of collaboration through the National Central Library and Aslib; but in general they operate as isolated units.

(g) Commercial libraries and information bureaux

Some of these, like the library of the London Chamber of Commerce, serve the commercial interests of the area; others, such as the Export Group for the Constructional Industries, act as clearing-houses for information for certain types of industrial concerns. With these should probably

be grouped those organizations which supply information on the applications of certain products, such as the Iodine Educational Bureau, the Boron Agricultural Bureau, the Copper Development Association, etc. In spite of the fact that propaganda on behalf of the commodity concerned is one of the reasons for their creation, many of these centres hold much valuable statistical and technical information and in most cases such information is freely accessible to those interested.

(*h*) *Individual libraries*

The great private family libraries are humanistic rather than scientific in character, but every individual scientist will accumulate his own selection of books and papers according to his means.

(i) *The National Central Library*

The National Central Library in London maintains a central store of the more highly specialized or expensive books for loan, but its chief importance lies in its work of co-ordinating the system of book loans throughout Great Britain. It performs an invaluable function in that it draws upon the resources not only of the public and county libraries, but also on nearly all university libraries and on many specialist collections. The library is not a reference collection but any serious student can call upon the services of this great national inter-lending system through his nearest public, county or other library.

In the National Central Library we have an organization capable of great development and to it might usefully be linked many of the national bibliographical services which would so greatly help the dissemination of information within the country. One such service would be a central index to British university theses, both published and unpublished, and an indication of researches in progress. Another suitable piece of work would be the maintenance of national union catalogues of periodicals. What is required is some central organization, such as the National Central Library, that can record all changes and accessions to these catalogues and can periodically issue supplements or new editions. It is a commonplace to say that any union catalogue, such as the *World List of Scientific Periodicals*, the N.C.L.'s own Union Catalogue of Periodicals in University Libraries, and the *British Union Catalogue of Periodicals* (now in process of compilation), is out-of-date as soon as it is printed.

There are many other bibliographical services which might be linked with the National Central Library, such as some form of national indexing or abstracting service, special provision for contacts with other national bibliographical systems, and loans between Great Britain and other countries : in the last mentioned instance the N.C.L.'s pre-war experience would be invaluable. In any case its work should receive fuller and more practical recognition so that its services and possibilities need no longer be handicapped by inadequate financial support.

(ii) *The abstracting services*

Abstracting in Great Britain is at present carried out by a number of independent bodies, ranging from *Science Abstracts* which is linked with

the Institution of Electrical Engineers, *British Abstracts* which is associated with the chemical societies, the engineering abstracts issued under the aegis of the Institution of Civil Engineers—through abstracts on more specialized fields such as those issued by the Imperial Agricultural Bureaux, the Institute of Metals, the industrial and other research associations and professional institutions of all types—to those published by the technical press or compiled and circulated for their own internal use by large industrial and commercial undertakings.

Unfortunately these widespread activities do not necessarily mean that the scientific field is adequately covered. There is a great deal of overlapping as far as the better known journals are concerned, whilst others escape notice altogether. Some sciences and advanced technologies, notably the social sciences and physical planning mentioned above as comparatively newly emerging studies of key importance in the fulfilment of our commonwealth responsibilities, are entirely without abstracting services. The whole question of abstracts is controversial, but if we are to have an efficient net-work of communications it is one that must be faced.

The results of original research, except when prohibited by the need for 'security' in time of war or by the desire for trade secrecy, are generally published in the form of papers in scientific or technical publications. The scientist's interest, therefore, is in the individual paper but, under the present system of publication, this may have appeared in any one of a number of different journals and some may be printed in periodicals whose usual range of interests is far removed from that of the scientist concerned. In present conditions, therefore, no scientist can be quite confident that he has seen all the papers relevant to his work and even if he could subscribe, or have access, to all the journals which might contain matter of interest to him, it would be physically impossible for him to read all the articles and books concerned. Therefore the development of a secondary form of publication, i.e. abstracts and lists of references, is necessary in order that he may be presented in a shortened form with a survey of the current literature on his subject.

The results of recent conferences seem to show that although much waste and duplication of effort might be avoided by the adoption of centralized national systems, internationally linked, such services could never be the final answer to the needs of highly specialized scientific or industrial research. There is probably no form of abstract that can be devised that can be absolutely certain of indicating all those aspects of a paper which may be of interest to a particular scientist. To take a very obvious example, a medical paper, which discusses the results obtained by the examination of a specimen by the use of a particular type of photographic apparatus, will be abstracted completely differently according to whether the abstract is intended for the use of a medical man or for one interested in the development of special photographic apparatus.

Some form of compromise seems the only solution. It should be possible to devise a central abstracting service which would, on the one hand, give sufficient indication of the contents of a paper to allow subsidiary specialist abstracting services to select those items which are worth re-abstracting from a special viewpoint, and, on the other hand, would be so standardized

in form that the items could be exchanged with those produced by the abstracting services of other nations.

(iii) *The British Society for International Bibliography*

This organization brings together those who are interested in all aspects of pure and applied bibliography in Great Britain. In addition, as the British National Committee of the Fédération Internationale de Documentation, it links British bibliographical interests with the international system, particularly as expressed through the development of the Universal Decimal Classification.

(iv) *Aslib*

The Association of Special Libraries and Information Bureaux, founded in 1924, was primarily established to foster co-operation between information users and to act as a guide to libraries and other sources of specialized reference material. It has held twenty Annual Conferences at which a wide range of subjects has been discussed and it is concerned with the improvement of the collection and distribution of information, specially in the scientific and industrial fields. Aslib publications, particularly its *Conference Reports*, the quarterly *Book-List* of recommended scientific and technical books, and the *Journal of Documentation*, serve to extend its influence amongst and beyond its present membership.

During the war the Aslib Microfilm Service, referred to in Mrs Moholy's paper, provided research workers in this country and abroad with copies of scientific publications from enemy and enemy occupied countries where the originals would have been inaccessible. Aslib also organized emergency training courses in special librarianship. It continues to encourage the library training of personnel in industrial and other special libraries and information bureaux and organizes lecture courses and other aids.

In recognition of its work, Aslib is now linked with the D.S.I.R. on terms similar to those of the industrial research associations and is thus in a strong position to co-operate with those engaged in scientific and industrial research both in this country and overseas.

3. THE NEEDS OF THE FIELD AND RESEARCH WORKERS

If we turn from the library system and communications net-work as they exist at present in Great Britain to the needs of the scientist, we find that they do not match. The needs of the scientist may be roughly divided into those of the workers in the field and mainly concerned with the applications of science, and those of the fundamental research workers. To take the field workers first. This is a vitally serious aspect of Empire science. In every part of the Commonwealth development programmes are under consideration or in progress. The forestry officer, the colonial medical officer, physical planner or economist must have all relevant documents fed to him without delay. In the first place he must have at his local centre at least an efficient ' working library ' of standard works of reference, the more important journals in all the fields of work which concern him and all the relevant abstract journals. Here at once we come upon a weakness. For reasons given above there are fields which are not

yet adequately covered by abstracting journals. Nevertheless because of the scattering of articles, few of the smaller ' working libraries ' can afford to subscribe to enough of the existing abstracting services to be sure of making use of all that might be available. Each working library should be able to link up with a centralized system so that it could directly receive a supply of the more relevant items. In any case, the information officer attached to the working library should scan abstracts covering adjacent fields for articles which have a bearing on his subject though their primary object may be something different.

A direct service for the provision of original copies of publications or of photo copies must also be established for the field worker. This involves more than a leisurely postal service and a process of ' searching.' For certain types of material the scientist now has access to the resources of the industrial research associations and of such learned or professional institutional libraries as may be open to him through membership. Beyond this it is now a hit-or-miss affair, ameliorated only by the valiant efforts of the National Central Library and the Science Museum Library, in which success is largely the result of personal contacts developed by the information officer. What is needed is a great strengthening of central libraries, both in the Dominions and in Great Britain, organized both to supply individual publications and also large-scale bibliographical services, such as union catalogues, the preparation of analytical bibliographies, etc. With this should go an encouragement to groups of special libraries to combine for certain services of inter-communication. There is already a slight movement in this direction. Thus a number of the Sheffield industrial firms, having many common interests in the metallurgical field, co-operate through the Sheffield Public Library in an inter-lending scheme which, by obviating the necessity for each library to subscribe to the same list of basic journals, enables their combined holdings to spread over a much larger, and more valuable, field. Co-operative bibliographical and library services in architecture and medicine have already been noted. Needless to say, each of these groups should be linked up with any central library service.

If bibliographical services are to be centralized, the equipment at every stage in the system must be efficient. Microfilming as an aid to documentation is at present handicapped by ambiguity concerning the copyright laws. There should be international agreement as to what classes of material can be reproduced and what restrictions are to be placed on the use of the film copies. If microfilms are to be used there must be good distribution of reading machines. Where documents are to be handled in great quantities and the inter-relation of subjects is complex. tabulating machinery as applied to documentation should be installed and there should be automatic selection. Attention should also be paid to the possibilities of radio or cable photo-transmission of documents. This has been applied for message services in the U.S.S.R. and is of course widely used for the well-financed news photographic services. There are no reasons, other than economic, why it should not be used for the facsimile transmission of documents. The centres should provide efficient translations prepared by other special libraries and research associations.

The services described above as needed for the field worker, usually a

technologist or a man dealing with applied sciences, are in general also needed by the research worker and the fundamental scientist. The latter, however, will often live nearer to library centres and can be expected to make more personal use of the library itself. Microfilms and systems of loans will be less important for him though he will still need them at times. The abstracting services and other bibliographical aids remain necessary. Above all, in order to counteract the isolationism which the scientist's pre-occupation with his own particular field of research must inevitably develop, he must be served by qualified intellectual liaison officers.

In many cases a busy research worker cannot hope to read for himself more than a fraction of the world's literature on his subject. He must depend on the efficiency of abstracting services and on the alertness of his librarian or information officer to bring to his notice selected items of special importance so that there is an increasing weight of responsibility to be shouldered by these officers. In a small library the work may have to be done by the librarian himself but then his professional qualifications as a librarian must be supplemented by a scientific qualification or long experience, in collaboration with technologists, of handling this specialized material. Many industrial firms find that the need for this scientific knowledge is so great that they tend to appoint as librarians men who have scientific rather than librarianship qualifications. Too much emphasis on this side, however, can have its dangers for the efficiency of the library. The purely specialist information officer, however brilliant, must have the backing of a first-class librarian. Alert though an information officer may be to the needs of the research workers in his organization, the service that he can render will be vitiated if he cannot swiftly and surely locate the documents required. Directly a library attains any size a knowledge of the technique of librarianship is required. Cataloguing, indexing, classification, filing, are not mere academic 'trimmings,' they are an integral part of the skill required to keep a library smoothly functioning. Moreover a small library started on amateur lines will be hampered in its growth, and sudden expansion under the pressure of necessity may produce chaos.

The functions, and therefore the training and qualifications needed, are not identical for librarians and information officers. No one would minimize the importance of the work undertaken by the larger reference departments of the public libraries, nor could they deny the efficiency with which it has been carried out by professional librarians. Nevertheless there is a difference between the work of the reference librarian, whose primary job it is to know where to obtain the information for which he is asked, and that of the information officer, whose task it is to assess the relevance or value of information in relation to the research being conducted in his organization and to circulate it where required in the most efficient manner. The special librarian should be one who is professionally trained in librarianship but whose scientific knowledge or special experience fits him for work in a library having a particular bias towards one group of subjects. An information officer should have special technical or scientific qualifications combined with enough knowledge and appreciation of library technique to enable him to use library tools to the best advantage.

In a library of any size there is need for both types of staff working in close collaboration. Special librarianship is itself experiencing the pressure towards yet more and more specialization and, as in science, is having to make use of more and more complex tools. Few people working in the field of special librarianship would be prepared to say that we have yet achieved clarity in differentiation and co-ordination of function. This largely is a task for the profession of special librarianship to work out and we cannot expect the working scientist to do it for us.

There is, however, one special field which needs immediate attention. Largely as the result of progress achieved in America the library world must prepare itself to use advanced systems of tabulation and selection to a much greater extent than hitherto. There is no doubt that many librarians trained in traditional methods and lacking mechanical or mathematical abilities view with alarm some of the advances in technique such as have been suggested recently by Dr Vannevar Bush of the Massachusetts Institute of Technology, involving complex integration of photographic and mechanical selection techniques. Special libraries must be prepared to meet advanced scientific demands in advanced scientific ways. Possibly a committee should be appointed to watch the development of advanced techniques with a view to their utilization by information services. The hesitant and spasmodic development of microphotography is an example and a warning.

4. THE PROSPECT BEFORE US

Looking at the library system and the information services as they now exist and at the needs of the scientist in the present atomic age, the first and obvious comment is that, apart from the National Central Library and the Department of Scientific and Industrial Research and the Imperial Agricultural Bureaux, there is no national recognition of the vital need for a fully developed information service. Two alternatives seem possible. Either we can continue the present haphazard system of development or there must be a fully organized State system which can give a complete and national service independent of private libraries, on the lines of the library system of the Academy of Sciences of the U.S.S.R. or the service. in its own field, of the Surgeon-General's Department in the United States of America.

The disadvantages of the first are plain. However much the professional and learned institutions are encouraged to co-operate, under present conditions they cannot expect to receive advantages which will adequately off-set the loss of privileges which they owe to their members. Similarly trade jealousy and suspicions will tend to prevent full collaboration between industrial and commercial libraries. Moreover the development of centralized bibliographical services, essential if the information net-work is to be complete, might be indefinitely postponed because, although such services would ultimately function to the benefit of all, they are the immediate responsibility of none.

At first sight, therefore, a State-supported and State-controlled system of information services would seem to be the answer since it alone could have the funds to set up centralized services and thus overrule the reluctance of certain types of library to participation in widespread

collaboration. The remedy, however, might be worse than the disease unless there is a radical change in the attitude of the State, as expressed through the machinery of the Civil Service, towards library matters. Everyone knows that there are intelligently organized and active Government libraries and information services but there are also departments where the librarian is equated with the clerical worker and there are few where previous library experience or qualifications are considered essential. A glance through *Whitaker* will show how seldom the librarian or information officer is mentioned by title. The fact is that the Civil Service, although it recognizes that the scientist has qualifications apart from his seniority within its ranks and that he cannot be shifted from one place to another without regard to these qualifications, does not recognize librarianship as a qualification in itself.

Time and the pressure of public opinion may remedy this position as it has already improved the relations between the sciences and the State, but some of the Government libraries suffer under more serious disadvantages which are the outcome of their historical origin. The Patent Office and its library come under the Board of Trade, the Science Museum Library is linked with the Science Museum and the Victoria and Albert Museum under the jurisdiction of the Ministry of Education. These libraries are two of the chief resources for research material available to industrial scientists and librarians and as such their functions differ considerably from those of the libraries of the Board of Trade or of the Ministry of Education. It is seldom satisfactory when libraries are dependent for their development on bodies with which there is no close similarity of experience and outlook and this condition of affairs has special repercussions when it comes to the question of any development where the Ministry or Board concerned would have to approach the Treasury on behalf of the libraries. Moreover, it is seldom appreciated that the clerical workers in the accessions or other departments of a library are an integral part of the library machine and that the skill of trained cataloguers or librarians may be largely vitiated if the clerical workers on whom the library routine must ultimately depend are liable to be shifted at short notice and are interchangeable with staff serving in other departments which have no connexion with library interests.

These two libraries have been picked out for special mention because of their importance in relation to science and technology but the disadvantages of the present Government library system could be illustrated in many other instances. To extend such a condition of affairs to a nation-wide service might be disastrous. If the State is to organize and control the nation's information services it must be through qualified personnel, recognized as such by the Civil Service, recruited and remunerated accordingly, and coming under the administration of those who themselves both understand and appreciate the importance of inter-library work.

A third solution, possibly suitable to immediate needs, would be a combination of Government encouragement and private enterprise such as is shown in the system of the industrial research associations linked to the Department of Scientific and Industrial Research. This system has great merits. The Government grant does not come into operation until

there is evidence of a need for the particular research or service and also proof that it has the support of that section of the community which it is designed to serve. The grant is, in fact, proportionate to the subscriptions received by the organization from its members and therefore serves as a direct encouragement to initiation. Success brings its reward in the form of larger grants which can be used to develop other schemes which in their turn improve the service, and by so doing augment the membership still further. On the other hand the organization retains its autonomy and is free to try experiments unhindered by the necessity to seek Treasury sanction before expenditure. It is just this type of flexible relationship between State support for schemes which, in this initial stage, cannot be expected to be financially self-supporting, and full scope for private initiative, which is needed to integrate the immensely rich resources of the world's libraries and to make them serve the needs of the research worker.

Whatever system is followed in an attempt to co-ordinate information services, the first necessity is a survey of existing libraries and information net-works in Great Britain and the Empire which would have to be sponsored, if not carried out, by the Government. It would then be possible to see the most serious weaknesses and gaps, only a few of which have been so far indicated. Where suitable, encouragement could be given to appropriate existing organizations to extend their activities to cover these gaps, others would have to be bridged by Government action. In particular it would be necessary to see that the flow of information between the different parts of the Commonwealth was a two-way affair. These scientific liaison offices should be immediately linked with efficient documentary reproduction services to facilitate the transmission of urgently needed material pending the creation of really good library centres in those parts of the Empire which still lack them.

Ambitious schemes have been outlined in this paper though they are not more ambitious than the seriousness of the problem warrants. No scheme, however, can be successful unless it is operated in the condition that it is desirable and indeed necessary. The first essential is, therefore, the acknowledgment by the British and the Commonwealth Governments of the vital need for the establishment of a better scientific information service. Once the principle is admitted, the details can be implemented.

APPENDIX A

Problems for discussion

1. The need for the recognition of the importance of planned libraries and library information as part of the necessary machinery of national life.
2. The development of international scientific information links.
3. The development of British information services overseas.
4. The training and status of personnel in information services.
5. The development of national bibliographical services.
6. The creation of centralized national bibliographical services.
7. Subsidized documentary reproduction services for the aid of scholars and research workers in those parts of the Empire where adequate library facilities have not yet been developed.

APPENDIX B

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A CENTRAL OFFICE OF DOCUMENTARY REPRODUCTION

By Lucia Moholy

It is becoming increasingly evident that Documentary Reproduction is an invaluable aid to science and learning and that its importance is bound to increase further in the very near future.

Most of the existing services for Documentary Reproduction in Great Britain are attached to libraries or scientific institutions. Their scope is generally limited to the supply of extracts from books and periodicals available on the premises. With the growing and at the same time more specialized needs of science and learning, the resources of individual libraries and institutions may no longer be adequate. The obvious remedy is to establish co-operation, with other similar institutions for the loan of books and periodicals or for the exchange of reproduction services. Efforts to co-ordinate on a small scale at least, the services already in existence, have led the way to a new type of unit such as the Aslib Microfilm Service which operated on these lines during the war years. Through an organized system of library contacts this new type of service will be able to combine bibliographical with technical facilities and by doing so it will be qualified to serve scholars and men of science speedily, efficiently and economically.

With the advent of modern micro-copying techniques, the scope of Documentary Reproduction has assumed much greater proportion than ever before. (A list of tasks and potential tasks likely to materialise in the near future, follows overleaf.) Owing to the extended range and the specific character of the tasks ahead, Documentary Reproduction is now intricately bound up with a number of problems each of which forms part of a complicated system of relations and inter-relations in the world of science and learning. Whilst hitherto Documentary Reproduction was a transaction between two main parties, care will have to be taken in future of many and varied interests.

There is little doubt that Documentary Reproduction tends to make quick and vigorous progress, but the foundations of such progress have not yet been laid. While provisional agreement has been reached on a small number of elementary matters, questions of major importance affecting method, procedure, economy and general policy have barely been touched. If the paramount question of demand and supply is to receive effective attention, a general policy covering those major problems will need working out.

In order to prepare the ground it is suggested that a Central Office of Documentary Reproduction should be set up in London with terms of reference on the following lines :—

(*a*) To co-ordinate all services of documentary reproduction and co-operating institutions, including university departments, university libraries, Government departments, and learned societies in Great Britain and the British Commonwealth.

(*b*) To establish close co-operation with all bibliographical centres in Great Britain and the British Commonwealth through the National Central Library and other co-ordinating institutions.

(*c*) To organize and co-ordinate in Great Britain and between Great Britain and the countries of the British Commonwealth the demand and supply of documentary reproduction (covering bibliographical and technical services).

(*d*) To organize permanent exchange of experiences regarding scope, character, method, procedure, economy and policy between all centres of documentary reproduction in Great Britain and the British Commonwealth with a view to achieving effective co-operation all round.

(*e*) To establish and maintain contact and to exchange services and experiences with central offices for documentary reproduction in other countries with a view to supplementing scientific information from all available sources.

(*f*) To staff and equip a technical unit competent to supplement the services of the co-ordinated centres for documentary reproduction and to take care of tasks which, owing to their complex character, can only be executed in close liaison with the central administration.

(*g*) To undertake and carry out all administrative tasks arising from the activities under (*a*)–(*f*).

(i) Issue of limited editions which may not justify the cost of type-setting ; for example, dissertations, theses, private editions.

The cost of a microfilm negative is comparatively low and can easily be covered by a slight increase on the cost of each positive. From an existing master negative, copies can be supplied individually upon request. There is no need for a minimum number of copies to justify investment since the investment is negligible.

(ii) Publication of scientific papers which cannot be accommodated in existing periodicals.

A brief note or an abstract would direct the reader's attention to the fact that a paper is available in microfilm form. Particulars of author, title, cost, and address of supplier if other than the publisher of the periodical would enable readers to order their own copies.

(iii) Reports of laboratory and field work to be circulated among small numbers of subscribers.

(iv) Data sheets, figures, formulae, etc., to amplify papers or summaries published in periodicals.

Particulars including cost, and address of supplier if other than the publisher of the periodical, would enable readers to order their own copies.

(v) Re-publication of out-of-print books for which the demand is too small to justify new editions.

A provisional agreement on the microfilming of books was issued as a Joint Memorandum of Publishers and Authors in consultation with Aslib, and published in *The Bookseller* of 27 July, 1944.

(vi) Re-stocking of libraries

damaged or destroyed by enemy action ; depleted by purging and looting under enemy occupation ; or suffering from the consequences of war-time and post-war restrictions such as shortage of paper, transport, staff, etc.

(vii) Inter-library loans.

The supply of microfilms would eliminate waiting for books which are out on loan as well as the necessity of urging their return. The cost for the library would not be substantially higher. Some administrators claim that it would be lower.

(viii) Reproduction of card catalogues or sections of card catalogues not likely to be published in print.

This measure would enable different departments in a library to have their own copies of the main catalogue, and other libraries to acquire copies of important catalogues of which the originals are not readily accessible.

(ix) Saving of storage space in libraries and archives. This applies in particular to books and papers kept for record purposes and not normally required for reference.

The proportion of shelving space needed for the originals as against space for storing microfilm is in some cases as high as 100 : 1.

(x) Reduction in bulk and weight allows increased use of air transport.

(xi) Preservation of the contents of valuable manuscripts, early books, newspapers and other written or printed documents threatened with disintegration through age or other causes.

(xii) Protection from deterioration through frequent handling.

The life-time of a valuable document can be appreciably extended if the original is made accessible in rare instances only. Students will often find it quite satisfactory to consult films in lieu of originals.

(xiii) Facilities open to scholars in all parts of the world for studying documents without undertaking long-distance travel.

(xiv) Safeguard against destruction by fire, water, etc.

To render this safety measure effective, film copies must be stored in a place away from the originals. (All film used for documentary purposes should be non-inflammable safety film.)

(xv) Distribution of research material to serve men of science and letters, students and research workers.

Adequately organized, all-round co-operation in this field can develop a new type of service by combining scientific, scholarly and linguistic qualifications with bibliographical research and documentary reproduction. This new type of service, if centrally co-ordinated, might be a step towards the ultimate aim of keeping men of science and scholars currently informed of all the literature published on their respective subjects.

(xvi) Analysis and reconstitution of existing publications, to provide dossiers of material relating to specific subjects. A great improvement on subject catalogues, press-cutting files and similar aids.

(xvii) Supplements to bibliographical references not published with the paper or book, but available upon request.

A note in a suitable place would direct the reader's attention to these supplements and give particulars, including cost and address of supplier if other than the publisher.

(xviii) Educational activities and training schemes :—

(*a*) to relieve shortage of text-books and to supplement film strips ;

(*b*) as a help to children suffering from infantile paralysis (see item (xx)).

(xix) Re-education of children and adults in liberated countries.

To relieve shortage of text-books and teaching staff and facilitate co-ordinated planning to direct and supervise educational activities.

(xx) Relief, rehabilitation and instruction for hospital patients, in particular war casualties and cases of infantile paralysis. Special apparatus for microfilm projection allows bedridden patients to read or study without help and at their own individual speed.

This list could be further extended, but may suffice for the present. Its main purpose is to demonstrate new categories of tasks and in particular direct attention to those which are bound to involve a number of interests from various quarters and can therefore only be planned and organized by co-ordinated effort.

DISSEMINATION OF SCIENTIFIC INFORMATION

By Sir SHANTI BHATNAGAR, O.B.E., F.R.S., Professor M. N. SAHA, F.R.S. and D. N. WADIA, M.A.

THE selection of '*Dissemination of Scientific Information*' as a subject for discussion in the Empire Scientific Conference is itself a fitting recognition of the great importance attaching to the subject to-day. We are living in an era in which the discoveries of science, sooner or later, are found to modify not only group life, but even our everyday life. The endless series of discoveries during the present century, both during war, but more so in times of peace, have released new forces, created new possibilities, and raised issues hitherto unthought of, which have profoundly reacted upon existing social concepts and human relationships. In fact, our civilization to-day is in a process of far quicker transition than in any other period of human history. Dissemination of scientific information and news is essential for educating the public mind to appreciate the methods, possibilities and benefits and menaces of science. Science has become a public necessity and its deliberate utilization is necessary for promoting social welfare and economic betterment. It is hardly necessary to emphasize that an understanding of the spirit and service of science on the part of the people and their leaders can alone bring about such a transition in a peaceful and effective manner.

This war which has just ended in the victory of the United Nations was fought principally in the laboratories of the warring camps behind the armed forces. Never before was science regimented on a national scale for the prosecution of a major human affair such as the war. The striking success of science harnessed for military purposes has naturally suggested similar regimentation to build up a lasting peace. Scientific talent has already been recognized as a potential national asset and scientific research a matter for supreme national concern. This new attitude to science, particularly the recognition of its new social rôle, has provided fresh occasion for a review of the problem of the widest possible diffusion of scientific knowledge and information among the masses.

In March 1943, while the final issue of the war was still undecided, the Division for the Social and International Relations of Science of the British Association organized a conference on 'science and the citizen' and discussed ways and means for the public understanding and appreciation of science within a national boundary. Among those who have advocated dissemination of scientific informations on an international basis, Dr Joseph Needham has been the most enthusiastic, and his suggestion for an international science co-operation service has been widely discussed. The proposed United Nations Educational, Scientific and Cultural Organization (UNESCO), with its divisions on (1) humanities and

sciences, (2) education, (3) media of mass communication, (4) libraries, museums, exchanges, publications, special projects, and (5) organization issues, is largely expected to fulfil the need for such an international organization for the dissemination of scientific information.

In India, the need for the diffusion of scientific news and technical information was a late realization. This was inevitable in view of the fact that the development of science itself, on Western lines, did not take place until after the beginning of the present century. With the foundation of the Indian Institute of Science, Bangalore, in 1911 and the University College of Science, Calcutta, in 1916, higher education and research in fundamental science began to be seriously undertaken in this country. The establishment of these two great institutions was soon followed by the organization of science departments of other Indian universities, and a number of new research institutes were also founded. These developments gradually led to the formation of a strong school of science graduates and research workers. It was only then that the question of a common platform for the discussion of scientific problems and the diffusion of scientific information among people interested in science took a practical form.

In 1931, the Current Science Association was formed in Bangalore, which undertook the publication of a monthly science journal, *Current Science*, more or less after the model of the British weekly, *Nature*. The journal, with its fine get-up and good printing, received a ready welcome and provided a common forum for discussion of scientific problems in non-technical language as far as practicable. But its greater academic bias limited its use as an effective organ for the dissemination of scientific information among a wider circle of non-technical readers for which a different approach and outlook were necessary.

The Indian science news association

It was with the purpose of popularizing and spreading the knowledge and progress of modern science that the Indian Science News Association was formed in June 1935 as a non-profit organization, with its headquarters at Calcutta. The editorial article of the first issue of *Science and Culture*, the monthly organ of the Association, expressed the object of the Association and the journal in the following words :—

'Its object is dissemination of scientific knowledge among the public and advocacy of its application to all walks of life as far as practicable. The need of such a journal has long been felt, for, though India can now boast of a large number of workers in different branches of science some of whom have by their contributions won international positions, their labours are mostly confined to their technical subjects. It is true that they are neither wanting in capacity, nor are lacking in will to instruct the people by means of well-written articles about the progress of science and the advantages of their application to the economic and cultural life of the country. . . . Lastly, the view will be always kept in mind that science is important only as long as it conduces to the development of culture and serves the cause of human progress.'

The Association started with the gift of Rs. 1,000 from late Sir U. N Brahmachari, and of Rs. 2,000 from late Sir P. C. Ray, the Founder. President of the Association.* Although the main activity of the Association has so far been the publication of the monthly journal *Science and Culture*, it had also originally intended to start vernacular journals, and a school science journal to publish popular books, monographs and pamphlets on science and to organize popular lectures. None of this important work, however, could be undertaken for want of funds and dearth of enterprising workers in this untrodden field. Even for the publication of the journal, the Association has to depend on private meagre donations from industrialists and industrial firms.

In spite of these difficulties, *Science and Culture* is to-day the most important scientific monthly in India, admirably fitted for the task of dissemination of scientific information among the common non-technical people with an average liberal education. Besides popularizing science, it has ever insisted on the social aspects of science and on the application of science in national undertakings. The recent government interest in science and planning which have become manifest in the establishment of the Council of Scientific and Industrial Research and the Department of Planning and Development and in the undertakings of river and hydro-electric development works is largely due to the powerful advocacy of *Science and Culture* in these matters during the brief eleven years of its existence. In his general presidential address before the Indian Science Congress Association at Baroda in 1942, Mr D. N. Wadia paid a high tribute to the work of the two journals, *Current Science* and *Science and Culture* in the following words :—

' These papers through the unflagging missionary efforts of their editors have already reached a high standard of scientific journalism and are filling two important needs of the country—bringing together isolated workers in the different branches of general and specialized science and helping to mould public mind and governmental policies on such major issues as science education, national economic development and State aid to research. The vigorous espousal by *Science and Culture* of a policy of national planning, creation of a Department of Scientific and Technical Research and hydro-electric development has, it seems, reached the right quarters.'

Similar views were also expressed by Sir S. S. Bhatnagar in his presidential address before the Science Congress in 1944, when he stated : ' One must not forget, however, the part played by *Science and Culture* which always criticized the Government for lack of interest in matters scientific and for scanty provision of funds.'

Journal of scientific and industrial research

The Council of Scientific and Industrial Research, soon after its foundation, started the ' *Journal of Scientific and Industrial Research.*' The objectives

* Later, more gifts were forthcoming, one about Rs. 4,000 from Dr. S. C. Law, and Rs. 1,500 from Sir U. N. Brahmachari, Rs. 1,000 from the Burmah Oil Company, Rs. 1,000/- from Dr. B. C. Law.

of the journal are *firstly* to give publicity to the activities of the Council and to the results of researches financed by it and carried out in its own laboratories, and in the universities and research institutions in India, and *secondly* to establish a link between science and industry. From the number of inquiries received and its expanding circulation, it is clear that the services of the journal have received wide appreciation. Further measures for expanding its scope and service are being considered, and the Council is ever anxious to enhance the value of the journal as an instrument of science publicity and international collaboration.

The journal serves the interests of industry by publishing surveys of industrial raw materials, ' non-technical notes ' relating to processes developed under the auspices of the Council and notes on the more important developments in the industrial field. The publications issued by the Co-operative Research Associations in the U.K. are regularly abstracted in the journal. News of the activities of learned and professional societies in India, government measures concerning the interests of industry and reports on developments in various parts of the country, are published in the journal as regular features. Research papers bearing on technical and industrial advances and developments form a notable feature of the journal.

The work of the A.I.M.O.

So far as dissemination of scientific information related to industry and manufacture is concerned, special mention should be made of the good service rendered in this direction by the All-India Manufacturers' Organization, Bombay. The Organization issues from time to time short monographs on processes of manufacture underlying important industries, such as on rayon, rubber and ceramics industry. Useful pamphlets on planning, on schemes of heavy industries, village industrialization, on shipping policies, etc., have been prepared by experts and published. Such monographs and pamphlets have great educative value, and their publication in greater number and wider varieties covering all aspects of industries and manufacture should be encouraged in all possible ways.

Despite the commendable work of these journals and organizations referred to here, India has yet to make long strides in the direction of diffusion of scientific information among the people. When it is remembered that the circulation of these journals does not exceed a few thousand in a country of 400 million people, one begins to wonder whether any beginning has at all been made. These journals, in fact, cater to a small fraction of the educated population which itself represents an insignificant minority, and the vast population remains quite unaffected by such publications. This is perhaps inevitable in a country condemned to a low percentage of literacy, and until the percentage of literacy improves to a reasonable extent, popular scientific periodicals are hardly expected to make any headway as means for dissemination of scientific information.

The press, radio, scientific films, museums, etc.

Fortunately, however, scientific periodicals are not the only instrument for promoting public understanding of science and its methods. There

are other perhaps more effective ways which should now be explored. We refer to the press, the radio, the scientific films, museums and popular lectures. Special advantages of each of these methods have been well recognized, and it is important to see how far these have been developed in India.

Press. The importance of the Daily Press as an effective medium for diffusion of scientific information need hardly be over-estimated. Although sensational news of scientific development flashed by *Reuter* or other news agencies are seldom missed in the columns of the Indian newspapers, science reporting as a regular feature, like the sports, cinema or society scandals-corner, is almost unknown to the newspapers. The remarks of Professor J. B. S. Haldane with reference to the British press that more space is devoted to anti-science than to science is literally true of the Indian press.

During the war, an attempt has been made by most of the leading newspapers to introduce weekly science corners with varying degrees of success. Such efforts have been made possible owing largely to the fine, but subtle propaganda, work of the United States Office of War Information (USOWI) which regularly distributed, free of cost, science news letters containing abstracts of scientific papers on all branches of science, originally published in the U.S.A. Ready accessibility to these abstracts rendered the work easy for the sub-editorial staff, who often published them as such with acknowledgment to the USOWI. During the war the Bureau of Information of the Government of India showed some interest in the dissemination of scientific news. But what is ridiculous, the Bureau, instead of propagating information about scientific development of the country in an effective manner, took great pains in preparing abstracts of popular articles and notes appearing in British papers and flooded the newspaper offices with reports of the achievements of British science. Even the news letters released for notice in Indian papers by the Public Relations Officer of the Australian High Commissioner's Office contained information of scientific developments in Australia, however modest. In fact, the work of the daily press and the government agencies have been mostly carried out with a pair of scissors and gum bottle rather than with any directive brain.

Now that the war is over, the science service of every newspaper should be organized on a permanent footing. There should be permanent scientific features in every newspaper which will have to maintain intelligent science reporters on its staff. Moreover, scientific and technical advisers should be attached to every newspaper, and it should be the policy of the papers to draw editorial attention to scientific questions whenever such assume importance.

A SCIENCE NEWS SERVICE WANTED

We strongly feel that a *Science News Service* should be immediately organized in India, with representatives from universities, research institutes, private or government, and the industry. Science news writing should be a whole time job and young graduates specializing in different branches of science and having literary taste should be encouraged in the profession of science news writing. In this connexion, mention should be made of

the Institute for the Popularization of Science, U.S.A., which was organized in 1921 as a non-profit corporation. The Institute directed by Mr Watson Davis, conducts Science Service and publishes *Science News Letters*, being the weekly summary of the American current science. The fine service rendered by the Institute to the cause of diffusion of scientific information has hardly any parallel elsewhere. The members of its Board of Trustees are nominated by learned American societies, such as the American Association for the Advancement of Science, the National Academy of Sciences, the National Research Council, the journalistic profession, etc. In the conference of the British Association a similar proposal for the creation of a British Institute of Scientific Information was made by Mr Ritchie Calder, formerly science editor of the *Daily Herald* and by Mr Henry Martin of the Press Association.

The Indian Science News Association about which we have spoken earlier is the fittest organization in India which can assume the rôle of an All-India Science News Service. This would involve considerable expansion of its activities, including better library facilities, abstracting and bibliography services on an extensive scale, and permanent liaison between the Association and the universities, the government and the private research institutes and industrial laboratories. Adequate financial provision for such expanded activities which alone can attract promising young talent to this profession is the only bottle-neck for carrying out any such idea into practice. State aid for such service has been suggested, but the freedom of propagation of scientific information and constructive criticism on all scientific matters of national importance, in which the government of the country may be frequently involved, clearly require that any such state aid if forthcoming should be entirely unconditional. Such unconditional grants are made to the universities in support of higher education and research and a science news service organization dedicated to the cause of dissemination of scientific information, in which the government responsibility is inescapable, is also entitled to similar unconditional grants.

Radio. Radio as a means for diffusing scientific knowledge so far has been little employed in this country. Occasional scientific talks by experts have been broadcast by the All-India Radio ; but science as a regular feature in the programme has not yet appeared. Also the faulty practice of inviting highly academic men to deliver talks over the radio should be abandoned. Talking to the uninitiated public on scientific subjects is an art by itself, and until one has acquired it, his talks, though erudite, are destined to produce little effect on the listeners. There should be a science committee to prepare, co-ordinate, and direct a science policy in broadcasting, and also a regular commentator on passing events. Problems of industry, housing, agriculture, food, medicine, health, education and social habits, biography and topical science news should be regularly included in the programme.

Scientific films, and museums. These two important methods are quite undeveloped in India. Scientific films have been most successfully employed in the field of biology. Such films have a ready appeal and their use has been greatly advocated in Britain, U.S.A. and Russia.

Research information to industry

The responsibility for supplying research information to industry largely devolves on the Council of Scientific and Industrial Research. An important requirement is a comprehensive central library, and a well organized abstracting service. Such libraries have been rendering invaluable service for the advancement of industry in other countries. Following the system adopted particularly in the U.S.A., for conveying research information to industry, it is proposed to organize a library in which *all* research papers, technical reports and publications could be filed. Abstracts of papers will be prepared by the library and circulated at regular intervals to libraries, research institutions and other bodies interested in them. Copies of original papers will be available to those who need them, on payment of a small fee to cover the expense of photostating. A small nuclear library service exists at present but it has to be greatly expanded in order that it may fulfil this function on an adequate scale.

Other developments which the Council are contemplating are :—

Liaison with abstracting organizations in foreign countries with adequate arrangements for abstracting scientific literature published in India according to an agreed system. Classified and indexed abstracts for industry together with flowsheets and statistical analytical and other data.

Publication of monographs, bulletins and surveys of vegetable, animal and mineral resources of India.

The liaison officers to be appointed in different countries to be requested to contribute surveys of scientific developments in the country of their assignment for publication.

News sheets and leaflets on selected topics, presenting facts of science in the form of easily understood charts and diagrams to be issued from time to time.

Scientists in India have followed with interest the recent discussion in London and elsewhere on the dissemination of scientific information, and on ' a United Nations Educational and Cultural Organization ' published in *Nature* (10 November 1945), and will co-operate enthusiastically in the setting up of an organization for furthering the public relations of science.

COMPLETE DOCUMENTATION

By Dr S. C. BRADFORD, F.L.A.
(President, British Society for International Bibliography)

THE fact that the Royal Society has thought it useful to include the subject of information services in the programme of this Conference is welcome evidence of the growing appreciation of the need for organizing documentation.

The purpose of my contribution to the Conference is :

(*a*) To emphasize, what would be taken for granted in any ordinary subject, that the sound organization of documentation cannot be evolved without a thorough realization of the relevant facts and their implications ;

(*b*) to point out that these facts have been deduced by an international organization, which has evolved a simple comprehensive plan that has passed the experimental stage and achieved already a valuable information service available to its members ;

(*c*) to state the facts ;

(*d*) the stage of success achieved, and

(*e*) to propose that a committee should be formed, including expert representatives of the international organization, to consider in what ways the organization of documentation can be improved.

Will you allow me, then, to retread with you the road of long past years and quickly observe the salient features ?

The first attempt to found a comprehensive information service was made in Brussels by MM. Paul Otlet and La Fontaine, who met in 1892 and set to work to compile a comprehensive card subject index. The sequence of their ideas was well nigh inevitable. To realize a universal index, international cooperation seemed essential. The First International Conference on Bibliography was called for 1895. This led to the discovery of the most important fact, that to coordinate the work of many bibliographers, so that it could be fitted into one comprehensive index, a standard subject classification was imperative. The problem thus arose of choosing a sufficient system, which must be simple and yet completely comprehensive. The Dewey Decimal Classification seemed the only possibility. But no copy could be seen or bought in Europe. And one had to be obtained from the United States. This copy was received six weeks before the Conference met. And, in this short time, Paul Otlet and La Fontaine classified the whole 400,000 references they had, meanwhile, collected. If we remember that to classify 25,000 references a year is good, what shall we say of completing eight times as many, each, in about one-eighth of the time ? And yet the cards were ready for the critical examination of the delegates, who decided, then and there, to create an International

Institute of Bibliography and to adopt the Dewey system, for extension for the purpose of a comprehensive subject-index to the world's recorded information.

At first, the Institution had the double aim of realizing *by cooperation* a complete collected bibliography of intellectual literature and of supplying, to inquirers, integrated lists of references to the literature of any special subjects whatsoever. But, as the preparation of a comprehensive bibliography on a special topic, often necessitated reference to its literature, and, as inquirers needed to consult the volumes to which the bibliographies directed them, the dual aim was naturally expanded to include a third : the founding of a central universal library. So was the complete idea evolved.

A Utopian idea some called it, and, perhaps, it was. But it contained a kernel of practical necessity, which needed only weathering to release. Nor was this process wanting. The idea itself was new. There was no school of bibliographical opinion to support it. The need for a comprehensive index was not yet widely realized. So, from the time of its foundation, the founders of the Institute discovered that ' misfortunes travel in a train.' Almost every possible mischance befel them : loss of funds, expulsion from their premises, destruction of their archives, widespread ridicule and spurious imitation with the highest backing. Only their unshakable conviction, indomitable courage and steadfast determination, enabled MM. Otlet and La Fontaine to outlive the storm and remain, at last, the masters of a strengthened structure. We see, now, that the first complete conception was altogether much too vast. It was, in fact, Utopian ; beyond the comprehension of the public, who had not yet begun to understand the pressing need for any kind of comprehensive subject-indexes. Nor was it practicable, then, to collect, within a single library, the colossal output of the printing presses of the world. Support for such a tremendous project was not forthcoming, and thus the work has, usefully, been limited to the field of science and technology, in which there has arisen definite and logical demand.

Decentralization

Meanwhile, a further defect was revealed within the structure of the Institute. At first, the bibliographies, supplied in answer to inquriy, were prepared by voluntary collaboration of a group of scientific specialists, who had gravitated to the centre and gladly gave their services in aid. The four years' war dispersed this help, and, subsequently, bibliographies prepared were quite insufficient. The reasons for this were (1) that, initially, too few of published current bibliographies were decimalized ; and (2) that the Institute's non-technical assistants were unable to sort out the special references from the existing mass of uncoordinated bibliographies. And so experience showed the necessity for decentralization and for the employment of scientifically expert bibliographers.

In the light of this experience, scientific information centres were established in, or in connexion with, a number of large scientific libraries, in conjunction with the literature. These services employed trained personnel to search existing bibliographies and collaborated with existing information services, serving individual subjects.

The first of these new centres to be formed was the Dutch Institute of Documentation founded in connexion with the Dutch Patent Office in 1922 by the representatives of certain scientific and technical societies, government institutions and special libraries, under the secretaryship of Ir Donker-Duyvis. Just before the six years' war it had a staff including five engineers and about eight other trained men working part-time.

The Science Library had always done its best to furnish information asked for, but perhaps its recognition, as an information centre, may be said to date from 1926, when it became possessed of a half-million references that had been decimally classified by the French National Section of the Institute, and decided to cut up and intercalate with them, all bibliographies adopting the same system, of which the library had almost a complete collection.

In the previous year I had succeeded to the chief librarianship and was endeavouring to enlarge the library as a model instrument of bibliographical research ; to ascertain what literature was published, collect it in the library, make it available for reading, or for loan, and to supply, in answer to inquiry, the most extensive lists of references to articles and publications on any special subject ; or, in other words, to make recorded scientific information immediately available.

In justice to the British Society for International Bibiliography, I must record that that big task would certainly have been beyond my powers without the invaluable support afforded by the Society and its influential members, such as Sir Charles Sherrington, Dr Priestley, Sir Frederic Nathan, William MacNab and others.

The value of the library and its information service gained appreciation. Its card index grew, until it now contains about three million cards. This was supplemented by a very large collection of all kinds of unclassified bibliographical material, which was searched by experts in answering inquiries. Yet another defect now appeared. Because sufficient staff could not be made available, the information service was too slow. A supplementary staff was added with the aid of voluntary subscription. Then, the fact that the library information service was not charged for, was considered to prevent the charging of a fee for the additional services. In consequence these services could not maintain themselves and had to be suspended. As it happened, many of the voluntary subscribers were incorporated in the Society much to its benefit. And, since the war, its members can obtain comprehensive bibliographies or digests of the information on the subjects of their investigation at cost price from the information service of the Dutch Institute of Documentation.

The Swiss Committee for Documentation, including several information centres, was created in 1929.* In 1932 a centre was established at the library of the Berlin Technische Hochschule, while other smaller services were developed in some other countries. In every country, except perhaps in Great Britain, these documentary services have been accorded government recognition and received support from industry, which has made great use of the facilities provided.

* *Proc. Brit. Soc. intern. bibliog.* 1946. Janicki, W. The present state and future development of documentation in Switzerland.

In conformity with the idea of decentralization, National Sections of the Institute were also formed. The first of these to be created was, the Section Francaise, formed in June 1896, with Monsieur C. M. Gariel, General Secretary of the French Association for the advancement of science, as President, and Monsieur Marcel Baudoin as Secretary. Even at that date, the latter had already classified two million cards by Dewey's system, and he is still a member of the Council of the Institute.

Unfortunately, the formation of like National Sections of the Institute in other countries was prevented, almost certainly by the creation of the National Committees of the International Catalogue of Scientific Literature in every European country, as I shall shortly mention. And it was only when that catalogue had come to grief and the four years' war had ended, that the Institute was able to extend its organization by the foundation of effective National Sections in the more important countries.

Until that time the membership of the International Institute of Bibliography, except for the French Section, was restricted to its numerous individual members, with a few large specialized organizations, such as the Concilium Bibliographicum and the Fédération Dentaire Internationale. The former of these two was founded in 1890 and prepared and published a zoological card bibliography, deservedly regarded as the finest existing subject-index until, quite recently, the Rockefeller Trust, unfortunately, transferred its grant to a non-decimalized American publication.

After the four years' war, new National Sections of the Institute were created and, at the outbreak of the six years' war, their number had increased to twelve. These were in America, Belgium, Czechoslovakia, Denmark, France, Great Britain, Germany, Holland, Italy, Poland, Russia and Switzerland, while six others were in course of formation in Austria, Hungary, Norway, Roumania, Spain and Sweden.

The British Society for International Bibliography. This Society was founded in 1927 as the British National Section of the Institute. A prime object of the Society is to study all the facts concerning the production of documents and the publication of subject-indexes to, and abstracts of, the information recorded therein : to deduce from these facts the most efficient and economic method of organizing a comprehensive subject-index with the corresponding abstracts : and to organize the production of such a comprehensive means of locating all recorded information on each topic, large or small.

It follows, from the facts deduced, that the needed reformation is to establish the co-operation of existing, self-supporting, abstracting agencies, through the adoption of a standard classifying system, together with a means of covering all the useful articles between them.

Much progress in the first stage of the programme has been made. In 1927 the Universal Decimal Classification was practically unknown in England. Thanks to the activities of the Society, by 1935 there were eighteen abstracting periodicals using the classification in the country. Besides thirteen publications classifying their articles by the system and twenty-one institutions employing the classification for internal purposes. These numbers have continued to increase, and now some hundreds of

potential users are clamouring for the English edition, now being produced by the British Standards Institution, and more decimal classification entries, than published abstracts to different articles, are produced in abstracting periodicals and business files. It can confidently be expected that it will not be very long before each abstracted article will receive its proper classification numbers.

The second stage, the collaboration of existing abstracting agencies in covering all the literature, has been initiated, and we may look forward to the time when every useful scientific article will be abstracted or, at least, indexed by subject, in the appropriate abstracting periodical.

The achievement of these aims needs education of the public, which still does not realize the facts. For this purpose, this Society holds meetings, to which its members bring their friends, contribute papers and discuss the multifarious problems of documentation, including the organization of special libraries and information services. These papers and discussions are published subsequently in the *Proceedings* of the Society, now in its eighth volume. The Society plays its part in developing the Universal Decimal Classification, to keep pace with growing knowledge ; promotes co-operation between existing information services and assists its members in the organization of their libraries and the use of the Universal Decimal Classification.

The International Commission of the Universal Decimal Classification

Besides these National Sections and federated international bodies, the Institute maintains the International Commission of the Universal Decimal Classification, whose able and indefatigable Honorary Secretary is Ir Donker-Duyvis. On this Commission and its national committees, depends the great work of maintaining the Universal Decimal Classification abreast of intellectual progress.

The many valuable publications issued by the Institute include perhaps the most extensive current engineering bibliography.

Scope

All this time, the scope of the Institute has gradually and necessarily extended to include all aspects of the art of making information useful, as in the following schedule :

(*a*) The organization and standardization of documentation.
(*b*) The organization of documentation. Pedagogy and distribution of knowledge on documentation. (Preparation of international conferences. Meetings of National Sections to read and discuss papers by experts. Publication of the official journals of the F.I.D., ' Communicationes ' and of the National Sections, e.g. ' Proceedings ' of the B.S.I.B. Training of special librarians and information officers.)
(*c*) The standardization of subject-indexing. (The organization of the Universal Decimal Classification and the supply of extensions to keep it up to date.)

(*d*) The standardization of the form of bibliographical references. The size and make-up of cards and entries.
(*e*) The standardization of the alphabetical arrangement of references.
(*f*) The organization of scientific publication. (Standardization of the sizes and make-up of books and periodicals. Their indexes and abridged titles. Standardization of sizes of reproduction materials. Lists of periodicals arranged by subject. International directory of documentation centres. Collaboration of publishing institutions.)
(*g*) Terminology.
(*h*) The organization and practice of the supply of information. (Bibliographical references to literature. Abstracts. Organization to cover all the literature. Digests. Individual information services. Networks. Central bureaux of information. Exchange of information. Tariffs. Organization of the preparation of annual summaries of progress in different fields by recognized institutions.)
(*i*) The actual supply of information and photographic reproductions (including microcopies) by the F.I.D. and its national sections in cooperation with other services.

Statistical investigation *

Introduction. For complete realization of the present bibliographical chaos, the facts must be considered in detail. Investigators know that, from time to time, researches are pursued in ignorance of recorded facts. They know also that abstracting periodicals do not always abstract important papers on the subjects of their investigations. What they do not know is the extent of these deficiencies. If we would essay the removal of these defects we must deduce the facts concerning the recording of researches and the subject-indexing, or abstracting, of the records.

The lack of knowledge of inventors of the history of their inventions was established by the Director of the Dutch Patent Office, Dr Alingh Prins, who showed that hardly ever in technology do inventors know all that has been recorded relevant to their inventions. Some 65 per cent of German applications for new patents are refused, because the inventions are not new, and of the 35 per cent remaining, 31 per cent are limited in scope because the inventions are already partly known. This means that 96 per cent of those who think they have a new invention do not know the facts about it, and are repeating, to no good end, with much trouble and expense, work that is already done.

Collection of the data. The actual facts concerning the recording and abstracting of discoveries and inventions were deduced in detail by the British Society for International Bibliography under my direction. As the material necessary for such investigations could be found only in large scientific libraries, the statistical analyses were made, mainly in the Science Library, by a competent mathematician, my late colleague, Mr E.

* This part, up to and including the section headed 'The plan,' is extracted from a paper to be read at the International Conference on Documentation in Paris this autumn.

Lancaster-Jones. The library receives about 200 parts of scientific and technical periodicals a day and takes most of the abstracting journals as well as all the most important separate bibliographies.

By the daily examination of the parts received, it was established that about three-quarters of a million useful scientific * papers are recorded every year in 15,000 † useful scientific periodicals, and all the 300 abstracting and indexing periodicals together publish three-quarters of a million abstracts or references. But examination of these abstracts showed that they related to only about one-quarter of a million different papers, each paper being abstracted on an average about 2·7 times. This means that *less than half the useful scientific papers published are abstracted in the abstracting periodicals* and more than half the useful discoveries and inventions are recorded, only to lie useless and unnoticed on the library shelves.

Examination of the literature of a particular subject. This most disturbing fact demanded exhaustive confirmation. Only the most extensive of the checks we made need be recorded here. The total number of current periodical publications, devoted specifically to electrical engineering, is rather more than 400, of which more than 200 are of the highest or good class and will be called the ' useful ' periodicals. The residue is largely semi-technical or economic.

Of the 200 useful journals, 150 are received in the Science Library. All these were critically examined, as received, and were estimated to produce 9,500 useful articles a year.

Consequently, 12,000 useful articles may be taken as the annual output of the 200 useful periodicals. Similarly, the remaining 200 poor class periodicals were proved to contain annually about 13,000 papers of less value. Some of these articles might, doubtless, be of use, but, for this analysis, they were ignored.

Periodicals not specifically devoted to electrotechnology, as those on physics, transport, power and many other subjects, yield at least half as many articles, at a most conservative evaluation. While general periodicals, books, monographs, pamphlets, patent specifications, standards and government reports must yield as many more such useful documents relating to the subject. Thus, in all, we find a yearly *minimum* output of at least 24,000 useful articles and documents relating to electrotechnology.

In 1936 references to these documents were provided by eleven abstracting and subject-indexing periodicals, devoted to electrotechnology, producing a total of 27,000 references a year.

While ten general abstracting and indexing periodicals devoted to pure science and engineering, produced another 18,000 references a year in all. The aggregate of references to papers on the subject by these 21 abstracting periodicals was 45,000.

Further, it was found that only 40 of the 200 useful periodicals, and these the least important, were not indexed by any of the 21 sources; but no single abstracting or indexing periodical included more than 5,000 references a year.

The 160 periodicals abstracted corresponded to about 10,000 *different*

* The term ' scientific ' is used throughout to cover pure and applied science.

† The remaining 20,000 scientific periodicals contains mostly matter of less importance.

articles. But, normally, articles in periodicals not closely related to the broad subject, as well as books, pamphlets and patent specifications, were hardly noticed by these sources.

A rough determination of the duplication factor, for these references, gave a maximum average figure of 3·9. This figure is considerably higher than the general average of 2·7, and is due to the fact that electrotechnology receives so much attention. Similarly, the proportion of the references produced, namely 45,000, is high. But even this large number corresponds to only 45,000 divided by 3·9 or 11,500 different papers ; less than half the annual output of the useful articles. And no one source of references contains more than 5/24 or 21 per cent of the aggregate of references to different articles. So that all the 21 sources must be consulted, in their different arrangements, to gather references to less than half the useful records.

A number of similar analyses gave comparable results and thus established that no more than half the useful records of investigation are noticed by the abstracting and subject-indexing periodicals.

These tests suggested also the real reasons for this imperfection. Individual abstracting agencies concentrate upon the periodicals devoted to their special subjects with a few of those, the fields of which are closely allied to these subjects. For articles within their scope in ' other ' periodicals, these agencies rely upon the agencies concerned to abstract the subject, to which the ' other ' periodicals more specially relate. This practice does not suffice to pick up the majority of articles on the special subject, published in the ' other ' periodicals, for the simple reason that these articles are not within the scope of the abstracting agencies, dealing with the other periodicals and are not always abstracted by these agencies.

Another cause of the imperfection is that abstracting agencies generally ignore books, pamphlets, patent specifications and such like.

The scattering of articles on a given subject. It is, therefore, necessary to examine the extent to which articles on a given subject actually occur in periodicals devoted to quite other subjects : as, for instance, a paper on the mechanism of the heart, contributed to the *Proceedings of the Physical Society*, or one on genetics, occurring in an agricultural magazine. Investigation shows that this distribution follows a certain law, which can be deduced both theoretically from the principle of the unity of science and practically from examination of the references.

According to this principle every scientific subject is related, more or less remotely, to every other scientific subject.

It follows that, from time to time, a periodical devoted to a special subject may contain an article of interest from the point of view of any other subject. In other words, the articles of interest to a specialist must occur not only in the periodicals specializing on his subject, but also, from time to time, in other periodicals, which grow in number as the relation of their fields to that of his subject lessens and the number of the articles on his subject in each periodical diminishes.

There are always a number of periodicals covering subjects somewhat closely related to any individual subject, and a greater number of periodicals on subjects more remotely related to the given subject. The nucleus of periodicals devoted to the given subject, or to the smallest larger subject

containing it, must contain, individually, more articles on that subject than periodicals dealing with related subjects. In consequence, it is possible to arrange periodicals in zones of decreasing productivity, in regard to papers on a given subject, and the numbers of periodicals in each zone will increase as their productivity decreases.

Let m be the total number of articles on the subject contained in the periodicals in the nucleus. Let p, p_1, p_2 . . . be the numbers of periodicals in the nucleus and succeeding zones respectively, while r, r_1, r_2 . . . are the average numbers of articles per periodical in the different zones where

$$r = \frac{m}{p}, \; r_1 = \frac{m_1}{p_1}, \text{ etc.}$$

thus we have

$$p < p_1 < p_2 < \ldots$$

and conversely,

$$r > r_1 > r_2 > \ldots$$

Let us choose the zones so that

$$pr = p_1 r_1 = p_2 r_2 \ldots = m$$

consequently

$$\frac{p_1}{p} = \frac{r}{r_1} = n_1, \text{ say}$$

$$\frac{p_2}{p_1} = \frac{r_1}{r_2} = n_2, \text{ say}$$

where n_1 and n_2 are constants greater than unity. So that

$$p_1 = n_1 p$$

$$p_2 = n_2 p_1$$

$$= n_1 n_2 p.$$

Now we know no reason why n_1 and n_2 should differ, and the simplest supposition we can make is that they are equal. Consequently, in the simplest possible case, we get

$$p : p_1 : p_2 :: 1 : n : n^2,$$

which corresponds exactly to the expression derived, independently, from the actual facts, as we shall see.

The whole range of periodicals thus acts as a family of successive generations of diminishing kinship, each generation being greater in number than the preceding, and each constituent of a generation producing inversely according to its degree of remoteness.

The actual investigation covered, in the first place, the references quoted in the course of four and two and a half years respectively, by the current bibliographies of applied geophysics and lubrication, which are prepared in the library. These bibliographies were selected as containing many more than the usual proportion of references on such subjects: all the large collection in the Science Library of abstracting periodicals being consulted, as well as cumulated references classified by the Universal Decimal Classification and a large selection of the 'other' periodicals being scrutinized as they came in each day.

The source of each reference being given, it was possible to arrange the producing periodicals in order of their bibliographical productivity, the results are set down in columns A and B of tables 1 and 2 as follows :

TABLE 1. APPLIED GEOPHYSICS, 1928–1931 INCLUSIVE

A	B	C	D	E
1	93	1	93	0·000
1	86	2	179	0·301
1	56	3	235	0·477
1	48	4	283	0·602
1	46	5	329	0·699
1	35	6	364	0·778
1	28	7	392	0·845
1	20	8	412	0·903
1	17	9	429	0·954
4	16	13	493	1·114
1	15	14	508	1·146
5	14	19	578	1·279
1	12	20	590	1·301
2	11	22	612	1·342
5	10	27	662	1·431
3	9	30	689	1·477
8	8	38	753	1·580
7	7	45	802	1·653
11	6	56	868	1·748
12	5	68	928	1·833
17	4	85	996	1·929
23	3	108	1,065	2·033
49	2	157	1,163	2·196
169	1	326	1,332	2·513

TABLE 2. LUBRICATION, 1931–JUNE 1933 (FEW 1933 REFERENCES)

A	B	C	D	E
1	22	1	22	0·000
1	18	2	40	0·301
1	15	3	55	0·477
2	13	5	81	0·699
2	10	7	101	0·845
1	9	8	110	0·903
3	8	11	134	1·041
3	7	14	155	1·146
1	6	15	161	1·176
7	5	22	196	1·342
2	4	24	204	1·380
13	3	37	243	1·568
25	2	62	293	1·792
102	1	164	395	2·215

Column A gives the number of journals producing a corresponding given number of articles.

Column B gives the corresponding number of articles during the period surveyed.

Column C gives the running sum of the numbers of column A.

Column D gives the running sum of the numbers of column B multiplied by A.

Column E gives the common logarithms of column C numbers.

A glance at these figures shows that in each case there are a few very productive periodicals, a larger number of more moderate producers, and a still larger number of constantly diminishing productivity. In each case, by far the largest number of periodicals gave only a single reference during the whole period of the survey. No definite boundaries between the various classes are indicated, but the periodicals can be graded roughly according to the following basis :

(*a*) Those producing more than 4 references a year.
(*b*) Those producing more than 1 and not more than 4 a year.
(*c*) Those producing 1 or less a year.

In the case of applied geophysics (see columns C and D) :

In class (*a*) there are 9 sources producing altogether 429 references.
In class (*b*) there are 59 sources producing altogether 499 references.
In class (*c*) there are 258 sources producing altogether 404 references.

In lubrication, assuming that practically all the references relate to the two years 1931 and 1932 only :

In class (*a*) there are 8 sources producing 110 references.
In class (*b*) there are 29 sources producing 133 references.
In class (*c*) there are 127 sources producing 152 references.

The groups thus produce about the same proportion of articles in each case and the number of constituents increases from group to group, by a multiplier which, though by no means constant, approximates fairly closely to the number 5, especially for the two larger groups. This suggests that the running total number of articles given in column D might be proportional to the logarithm of the corresponding number of sources in column C, i.e. to the corresponding number in column E. And, in fact, if curves are plotted, as in figure 1, with E as abscissae and D as ordinates for both cases, the later portion of each curve is remarkably close to a straight line. We can thus say that the aggregate of papers in a given subject, apart from those produced by the first group of large producers, is proportional to the logarithm of the number of producers concerned, when these are arranged in order of productivity.

In the diagram, figure 2, let P_1 be the point at which the straight line part of the curve commences. Draw P_1X_1 and P_1Y_1 perpendicular to the axes of X and Y respectively. On OY mark off Y_1Y_2 and Y_2Y_3 each distances equal OY_1. Draw Y_2P_2 and Y_3P_3 parallel to Y_1P_1, cutting the curve in P_2 and P_3, and draw P_2X_2 and P_3X_3 both parallel to P_1X_1. Let the distance OX_1 be r units and the equal distances X_1X_2 and X_2X_3 be s units

in length. Then, if α, β, and γ are the natural numbers corresponding respectively to the logarithmic abscissae OX_1, OX_2 and OX_3 we have

$$\log \alpha = r, \text{ or } \alpha = 10^r.$$
$$\log \beta = r + s, \text{ or } \beta = 10^{r+s} = 10^r \times 10^s.$$
$$\log \gamma = r + 2s, \text{ or } \gamma = 10^{+2s} = 10^r \times (10^s)^2.$$

Putting $10^s = n$, we see that the natural numbers α β and γ are related to each other as $1 : n : n^2$.

The journals in the group represented by OX_1 form a nucleus of those more particularly relating to the subject in question. Therefore, the law of distribution of papers on a given subject in scientific periodicals may thus be stated : if scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus, when the numbers of periodicals in the nucleus and succeeding zones will be as $1 : n : n^2 \ . \ . \ .$

The question now arises, what limit can be assigned either to the aggregate of periodicals concerned, or the aggregate of articles produced, in any given subject ? We know that the former number cannot exceed the total number of useful current scientific periodicals, say 15,000. But all the data known relate to periodicals, actually discovered to contain useful papers, in preparing bibliographies.

How can we determine whether a mass of periodicals is in fact absolutely sterile in each subject, and how determine the number of periodicals that contain information on a subject.

One approach to this factor is suggested by the scope of the journals that contain useful papers.

On examination, we can establish that the (*a*) and (*b*) groups above mentioned are periodicals of scope obviously and *a priori* relevant to the subjects of investigation. They are journals which would almost inevitably suggest themselves as being concerned with these subjects, among others. On the other hand, the (*c*) groups are found to be very mixed, including some periodicals which, by their scope, we might expect to find more productive ; but including also journals of very remote scope in which we should hardly expect to find references. We are surprised, on the one hand, by the lack of productivity of the former, and, on the other hand, by the productivity of the latter. We can only draw the general conclusion that a large number of articles are produced by periodicals which, *a priori*, are ' unlikely.'

Again, if we examine the annual aggregate of periodicals concerned, we find that each successive year brings forth a new crop of periodicals, and that many periodicals produce a paper one year, but none in later years. In fact, in the applied geophysics case, each of the four years produced about 40 periodicals which gave a paper that year and none in the other three years.

Also, if we take the successive periods 1929, 1929–1930, 1929–1931 and 1929–1932, i.e. one-, two-, three- and four-year periods, it is found that the numbers of references arising from periodicals which produce not more

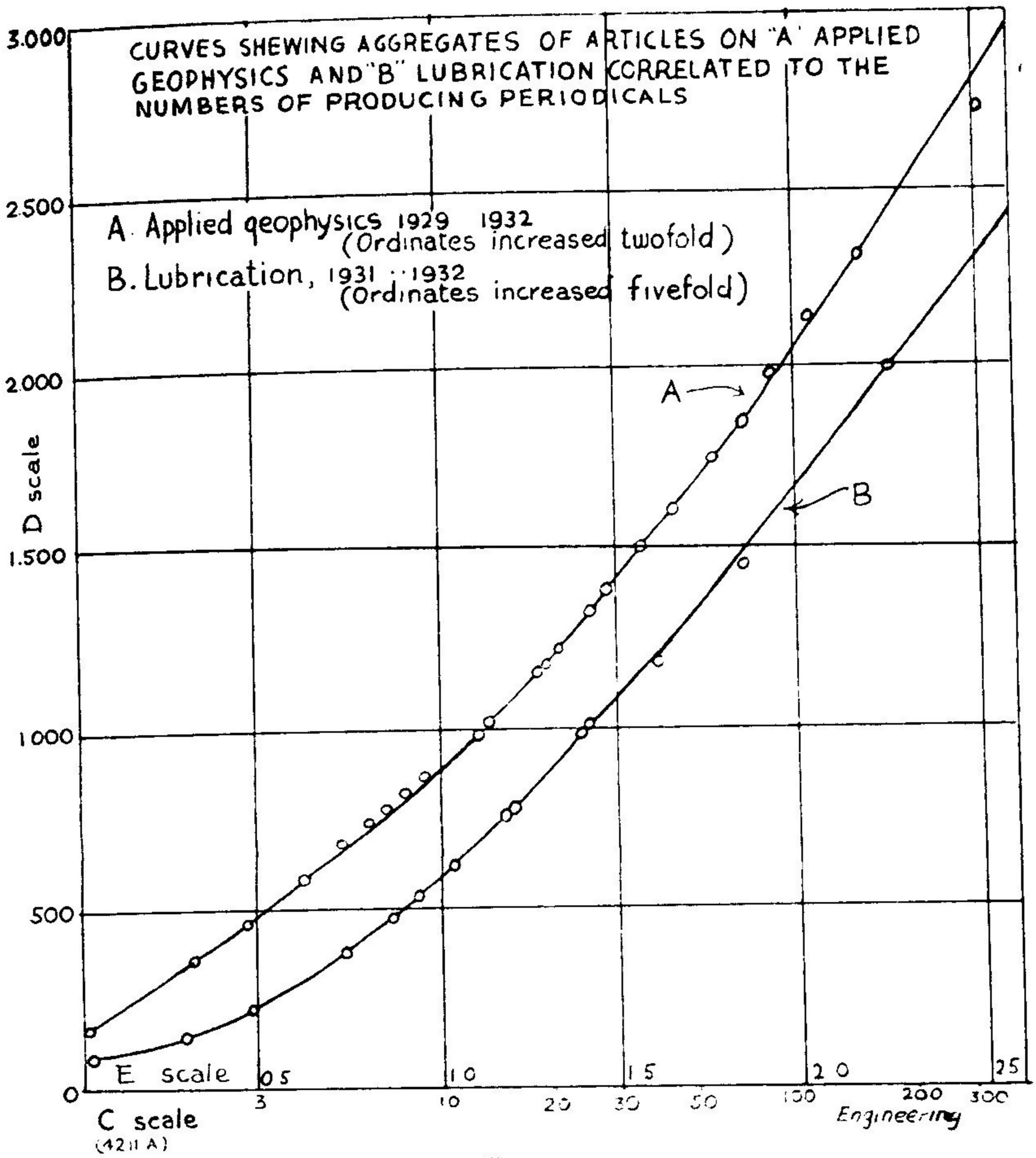

CURVES SHEWING AGGREGATES OF ARTICLES ON "A" APPLIED GEOPHYSICS AND "B" LUBRICATION CORRELATED TO THE NUMBERS OF PRODUCING PERIODICALS
A. Applied geophysics 1929 1932 (Ordinates increased twofold)
B. Lubrication, 1931 : 1932 (Ordinates increased fivefold)
A
B
3.000
2.500
2.000
1.500
1.000
500
0
D scale
E scale
C scale
0 5
1 0
1 5
2 0
25
3
10
20
30
50
100
200
300
Engineering
(42 II A)

FIG. 1

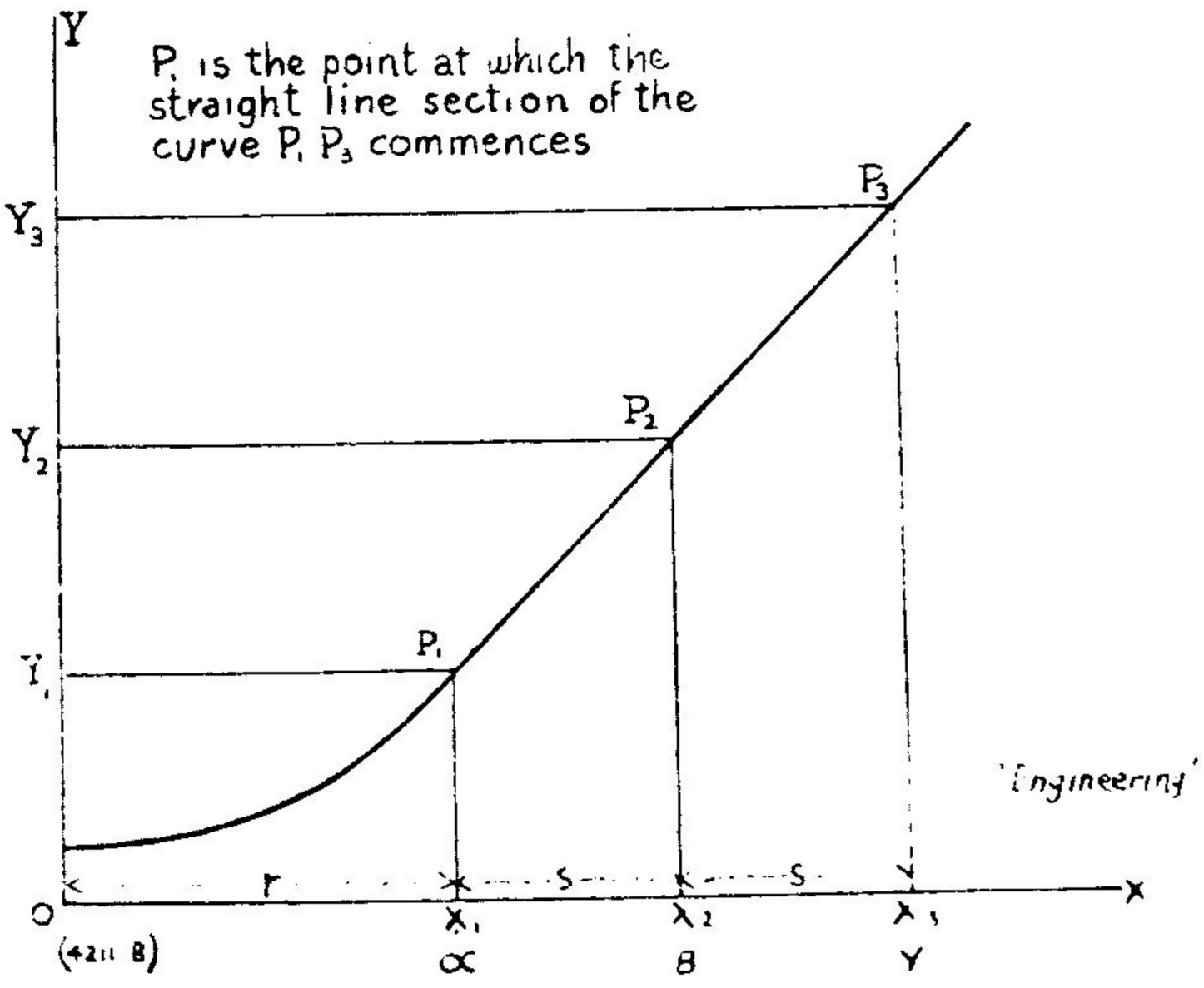

Y
P, is the point at which the straight line section of the curve P, P3 commences
P3
P2
P1
Y3
Y2
Y1
O
X1
X2
X3
X
S
S
α
β
γ
'Engineering'
(42 II B)

FIG. 2

than one article on the subject per annum is, in the four periods, 86, 184, 320, 404 respectively.

As each year produces about 350 articles, it may be deduced that, in any given period of years, the (*c*) group will produce approximately 25 to 30 per cent of the total quantity of papers. These will arise from periodicals which fluctuate over a wide range, and may in the aggregate involve a thousand or more periodicals.

It is conceivable that there could be specified in each of the two test cases a list of a thousand periodicals that would include all the producers yet found and all which might be found in a ten years' survey. But there is no means of ascertaining the limit necessary in any given case, and no guarantee that, in the bibliographical work a considerable number of articles have not been ignored.

In the lubrication case, it is significant that a small sample of journals, selected at random from a general list as being possible sources of articles, yielded in a ten-year survey 4 ' producers ' out of 14. These 4 produced only 15 articles in the ten years, none producing an average of 1 a year, so that all would come in group (*c*). Out of these 4, only one actually occurs in the list of producers in the bibliography 1931–1933, and this one is not in fact the greatest producer in the ten-year period tested. These 14 periodicals examined represented a sample, very small naturally, of the aggregate of regular journals dealing with general science, physical and chemical sciences and engineering and industry. This class would exclude periodicals of the annual or semi-annual type, and those dealing with natural history, medicine and other subjects less likely to produce references to lubrication. It might thus represent a sample of 14 from an aggregate of say, 3,000 possible periodicals of the former type. As, out of the 14, 4 were found to be productive, we get, as a very rough approximation, a figure of

$$\frac{2}{7} \times 3{,}000 = 850 \text{ (say)}$$

for the number of productive sources in a ten-year period.

Two further tests were made, each based on an examination of the relevant classes in the subject catalogue of the Science Library during a five-year period, in which about 500 periodicals, on all branches of science and technology, have been indexed. The tests showed that the lubrication references came from 14 periodicals, and the applied geophysical references from 19 periodicals. Assuming that the periodicals indexed by the library represent about

$$\frac{1}{30} = \frac{500}{15{,}000}$$

of the total number of similar periodicals in existence during the five-year period, we get the figures $14 \times 30 = 420$, and $19 \times 30 = 570$ for the numbers of actual sources of references on lubrication and applied geophysics respectively, in a five-year period. These figures are both considerably less than the figure 850 obtained above for lubrication periodicals, which is to be attributed mainly to the difference in the period of the survey, as will be seen.

Other considerations tend to confirm the hypothesis that the number of periodicals containing articles on the subject must increase almost linearly with the period of the survey. The number of known producers contributing not more than one reference a year to the geophysical bibliography were as follows :

86 in the year 1929
155 in the 2-year period 1929–1930
230 in the 3-year period 1929–1931
258 in the 4-year period 1929–1932,

and these form the major portion of the known sources, which were respectively 145, 218, 281 and 326. The increments each successive year are 73, 63 and 45, the last figure being probably smaller than it should be, because the survey of the literature of 1932 was still incomplete.

It is reasonable to assume that the known geophysical producers would increase over the whole ten-year period, though the increment might tend to diminish each year, say by 10 per cent.

Thus the number of known producers in a period of n years might be

$$S_n = a + (b + br + br^2 + \ . \ . \ . \text{ to } n \text{ terms})$$

$$= a + b\frac{(r^n - 1)}{r - 1}$$

where, for the geophysics bibliography,

$$\left.\begin{aligned} a &= 60 \\ b &= 85 \\ r &= \frac{9}{10} \end{aligned}\right\} \text{approximately}$$

giving

$$S_n = 60 + 850(1 - 0{\cdot}9^n)$$

or in the limit, the total number of productive periodicals, $S^n \infty = 910$.

Now, putting $n = 5$ and 10, successively, we have, for applied geophysics,

$$S_5 = 410$$
$$S_{10} = 615.$$

These are the ' bibliographical ' or ' known ' sources.

For lubrication, we know that a two-year survey produced 164 bibliographical sources compared with the 218 of applied geophysics, say 25 per cent less. We can, therefore, assume for lubrication

$$S_5 = 310$$
$$S_{10} = 460.$$

Comparing S_5 here with the value $S'_5 = 420$ estimated for the actual sources, we get a figure

$$S'_{10} = 460 \times \frac{420}{310} = 620$$

for the actual or total sources in lubrication, on a ten-year basis. Con-

sidering the approximate character of the analysis, this figure is sufficiently comparable with the 850 obtained above.

It seems safe to say, therefore, that the number of journals which contain articles on the subjects in question is of the order of a thousand. But the periodicals themselves could not be specified without scrutinizing a much larger number of periodicals during a long period. And, even when the actual producers during a period of years had been ascertained, new sources would certainly appear during a further period. It follows that the only way to glean all the articles on these subjects would be to scrutinize continually several thousands of journals, the bulk of which would yield only occasional references or none at all. And because this work is altogether impracticable, a large portion of the total number of references on a given subject is regularly missed by the abstracting journals.

For the same reasons special libraries cannot gather together the complete literature of their subject, except by relinquishing altogether their specific character and becoming practically general libraries of science. Detailed analysis showed that in practice one-third of the contents of special libraries is usually related definitely to their own scope, the remaining two-thirds comprising literature on border-line and less related subjects. These publications are duplicated in many other libraries, and their representation in any one is altogether inadequate.

The law deduced conforms to the mathematician's criterion of being of no possible practical use whatever. But it does show why abstracting periodicals are not complete and points out that, to remove the incompleteness, every useful article in every scientific periodical should be scrutinized, irrespective of the subject of the article.

To complete this investigation, it needs to locate some of the mass of hidden articles on a given subject, which are not indexed by the reference-making periodicals, and to make an independent estimate of the number of these articles from the articles themselves.

It has been shown how some of these articles were found in lubrication. Similar searches were made also in some other subjects such as chemistry and agriculture. To get a more reliable indication of their extent, it was required to deal with them in bulk. One of the largest groups of abstracting agencies, dealing with a single subject in *applied science*, was selected, because of the thoroughness of their abstracting. To avoid offence, the subject shall be nameless. We shall call it ' S.' One of the largest abstracting bureaux in *pure science* kindly allowed its abstractors to scrutinize the periodicals they dealt with for their special subject, we shall call it ' R,' and to pick out all articles in these periodicals that were of interest for the remotely related subject S. The number of articles a year, relating to the subject S and not abstracted by its own group of agencies, was found to be about 1,200. These were obtained from a group of 451 periodicals regularly scanned by the abstractors for the subject R. This number corresponds to an aggregate of nearly 40,000 articles on the subject S in the total 15,000 useful scientific periodicals. While the total number of the abstracts on the subject S, produced by its own bureaux, was only 20,000. So that they abstracted only about one third of the useful articles in their special field.

THE PLAN

It has been demonstrated that about 15,000 current scientific periodicals contain about 750,000 useful articles a year. Abstracting and indexing periodicals contain about as many references, but cover less than half these useful articles. The actual existence of the unnoticed articles has been traced and their number estimated independently.

The cause of this deplorable deficiency has been proved to be the scattering of useful articles on a subject throughout the mass of current periodicals. This makes it quite impracticable for a single agency to pick out all the useful articles on its special subject.

A comprehensive survey cannot be achieved by such a wasteful method. We must arrange, somehow, that every useful article in every useful periodical is dealt with as it comes out.

There are two different ways of accomplishing this task.

Either a new organization could be set up to index, or to abstract, each useful article in each useful periodical, independently of the subject of the article.

Or else the useful periodicals should be divided into groups, according to the subjects treated by existing abstracting agencies, and these agencies should undertake to pass on the articles, they do not abstract themselves, in the group of periodicals allotted to them, to the agencies interested in their subjects.

The former method would be extremely costly and extravagant as well, because it would duplicate the work of the existing skilled bureaux and it could hardly produce its index before the abstracting journals had prepared their abstracts. The method was put to the test, in a small way, in the well-known *International Catalogue of Scientific Literature*, which dealt with pure science only and came to grief. A complete scientific index would be seven times as big.

The latter method needs much less additional expense. Or, possibly, not any, if the Universal Decimal Classification is adopted. *No interference is involved with the internal work of any abstracting agency.* They can deal with and abstract as many periodicals as they desire, or finance permits, and publish their abstracts in any form and format they prefer ; all they have to do is to agree to be responsible for a *small* group of periodicals and to pass on the actual articles, they do not treat themselves in this small group, to the agencies concerned with the subjects of these articles.

A committee of well known abstracting agencies in England has been formed, which has accepted this important principle. Some steps towards co-operation have been taken, and it is confidently hoped that this collaboration will extend as the benefit arising is experienced, and as the principle is promoted in the other countries. By this means the abstracting periodicals, on each special subject, will grow more and more complete and only proper subject-indexing is needed to provide the information necessary to prevent the present waste of energy in duplication of research.

The comprehensive subject-indexing of all books, monographs, pamphlets, government reports, patent specifications and standards could be achieved by inducing a large general scientific library in each country to

classify its accession lists by the Universal Decimal Classification, as does the Science Library and by inducing Patent Offices and Standards Institutions to classify their publications similarly, as some do already.

Adversity

I must now relate a feature of the buffetings of fate, which might be properly described as the unkindest cut of all. I mean attempts by insufficiently informed societies or individuals to duplicate the organization of the Institute. All of these attempts, so far, have been eventually abortive. But they have diverted, or absorbed, much energy that otherwise had been available for progress. It is important to avoid them, if that be possible, in future.

The first and, possibly, the worse of these calamities befel in 1901, with the appearance of a bibliography, restricted to pure science only, with the title *International Catalogue of Scientific Literature*. This was the result of an International Conference, held in London, under the auspices of the Royal Society, in 1896. The feelings of our founders can be well imagined, when they protested that, as the project could not be put into operation for some years, the Conference was not forced to conclude immediately, without discussion, that all known systems of classification were unsatisfactory, decide to duplicate the work of existing experienced bibliographical concerns and to sacrifice to the problematical advantages of centralization, the results of a more federative organization, conserving the autonomy of its adult members. The Dewey System was established in America. Already many well-known European journals had adopted it. Could they be expected to take up another system, for no reason? The proposed new classification was not better. And, in any case, it was not a question of the best theoretical classification but merely of a standard means of arranging references, to make possible collaboration of so many bibliographers and bring their work together into a single index.

Despite these protests, the new catalogue appeared and ran for fourteen years. In the light of experience we see now that the organization was, in fact, defective in three respects. Its organizers had not appreciated the main principles of bibliographical classification. They did not realize the disadvantage of division of recorded scientific work by countries, rather than by subjects. Nor did they realize that scientific workers needed abstracts and would not support a list of subject-references without. In fact, the undertaking was foredoomed to failure. With lapse of time, the inefficiency of the inflexible notation adopted for the classification was exposed. And, when communication between different countries was dissevered by the four years' war, the catalogues of the pure scientific literature of separate countries could not, alone, obtain sufficient circulation, and were unable to compete with abstracting periodicals covering whole fields of science. And so the fabric fell to pieces, with a great financial loss. While the independent abstracting periodicals continued functioning, and *the total information indexed, annually, by the abstracting periodicals that used the decimal notation, eventually exceeded that included in the catalogue at best and goes on increasing.* The experiment, although expensive, proved the great superiority of the methods of the Institute.

Progress

With the failure of the catalogue, the Institution first obtained free scope. It held more frequent international congresses, working up to one a year. The education of the scientific public, in the necessity of comprehensive indexes and the waste of labour, time and money, occasioned by their absence, gradually proceeded. More and more abstracting agencies took up the standard code and collaborated in extending it, in step with growing knowledge, until a total of some 150,000 decimally classified references were made and published annually. While, at least, an equal number of similarly classified references were filed in business files.

New difficulties

And then in 1937 a new rival scheme appeared. Monsieur Jean Gerard, one of France's eminent industrial chemists, induced the Paris Institute of Intellectual Co-operation to hold a 'World Congress of Universal Documentation' for the purpose of creating a new International Institute of Bibliography, with its seat at Paris. As on the previous occasion, no valid reason was vouchsafed for the rejection of the Decimal Classification, now well up-to-date, or of the existing International Institute. Powerful support was gathered from authorities, in every other field than bibliography. And there is no doubt the project would have been achieved had not the International Institute, meanwhile, grown up.

In the event, the National Sections of the Institute, without exception, joined in the battle. The then President of the British Society, Professor Pollard, was unable to attend the Congress. But *he sent a letter to the Secretary of the Institute of Intellectual Co-operation, stressing that the methods of the International Institute and the British Society were sufficient to provide a complete index to the literature of science and technology.* Thus I had the honour to direct the British delegation, which included Professor Andrade from the Royal Society and Professor Hutton, founder of the Association of Special Libraries.

The Congress was most thoroughly arranged. At every meeting resolutions were proposed in favour of the plan. At first the members of the Institute were every time outvoted. But gradually, knowledge, experience and logic made their mark. And, after a most strenuous week, the Congress ended with the unanimous vote of more than thirty countries for the recognition of the International Institute. In consequence of the recommendation of the Congress, the Institute became the 'International Federation for Documentation,' to indicate fully its federative nature. And so adversity again proved faithful counsellor.

Further progress

From then onwards the Federation held its annual International Conference on Documentation, continuing to educate the public, extend its membership and National Sections and the number of the users of the Decimal Classification. So that the almost total interruption of communications, by the six years' war, could not destroy its life. Its National

Sections carried on and, with cessation of hostilities, the Federation automatically resumed control.

More difficulties

Yet, while the Federation was inhibited by the six years' war, this time two small black clouds appeared on the horizon. Two fresh proposals were put forth, on previous lines, for founding rival international documentary institutions. And so the periodical precipitation of disproved ideas continues. In the constitution of the Federation there is room for every useful bibliographical undertaking. May we not hope that these new incipient precipitations will dissolve in the warm sunshine of fifty years' experience and all will join in working for the progress of documentation.

To conclude

The lesson of these last fifty years of progress is, that the collaboration of existing, experienced, self-supporting, bibliographical institutions would be sufficient to provide the needed universal subject-index to the useful records of discovery and invention. The Universal Decimal Classification is now widely recognized as the means of this collaboration and has become a British standard. New applications of the code continually accrue. The number of the decimally classified entries has increased, until it should be comparable with the number of the different articles abstracted. Although each article should have perhaps an average of two subject entries, while the total output of such useful articles is still more than twice the number of those abstracted.

The removal of this deficiency is the most important of our remaining tasks. This can be accomplished by arrangements I have mentioned, for the scrutinizing, by existing abstracting agencies, of all the current literature. The inclusive sets of abstracts, so produced, would serve for compilation, by the same collaborating agencies of Annual Summaries of Progress in individual sciences. The abstracts would be filed, by subject in special libraries * and information offices, where the original literature is housed, for consultation, and the provision, by trained experts, of special bibliographies and digests for internal use, or on demand, and more scientific libraries need to be established in the Empire to bring recorded information to the hand of the investigator.

Such is the idea and such the progress made. We have come far indeed along the road. The way is clear. The goal comes into sight. It needs only that we march on in the right direction to attain the journey's end.

* *Brit. Soc. intern. bibliogr.* Publication No. 2. Bradford, S.C. The organization of a library service in science and technology.

THE DISSEMINATION OF SCIENTIFIC AND TECHNICAL INFORMATION ON ECONOMIC PRODUCTS

By G. T. Bray, F.R.I.C., Vice-Principal, Plant and Animal Products Department, and G. E. Howling, B.Sc., Vice-Principal, Mineral Resources Department, Imperial Institute

The fact that measures for improving the dissemination of scientific and technical knowledge are to be discussed at this conference implies that the existence of the need for improvement is accepted. The Imperial Institute has been engaged for the past fifty years in supplying information in respect of Empire raw materials, and we as members of its staff endorse this view. From our experience over a long period we venture to offer some observations on the requirements of the position. The present stage in the economic and political development of the British Commonwealth is indeed opportune for taking stock of the existing facilities for bringing to those who require it the information that becomes available in the different countries of the British Empire and elsewhere. It is the opportunity for improving and adding to the existing facilities. The following remarks have reference only to the dissemination of technical information regarding raw materials—plant, animal and mineral economic products.

The people who require more scientific and technical information for economic purposes include not only the planter and miner overseas, and the business firm at home or abroad, but also those in charge of the various Government Agricultural, Forestry, Veterinary, Geological and Mining Departments of all countries of the Empire. The problems on which information is sought concern a diversity of subjects, such as the choice of a crop to grow in view of the prevailing demand, and how to grow it; the preparation of a raw material for the market; the present and future demand for certain commodities; the improvement of existing methods of cultivation and preparation of various products; the location of ores and minerals and the assessing of their potential value; the uses to which raw materials are put; and the evaluation and commercial prospects of a raw material hitherto not marketed. Advice is also sought by Colonial Governors or higher officials on the broad issues of industrial policy, a potential development or a proposed change in a Local Ordinance.

In our opinion one central establishment for the service of the Home Country, the Dominions and Colonies is the most economic and efficient arrangement, as it avoids duplication of staff and equipment, and gives under one roof a centre for the collection of information from all parts of the world. It would be a comprehensive bureau of information for the whole Empire. If adequate publicity were given to the existence of

a central organization which could be approached for advice and information, the demand for such services would increase to very considerable dimensions.

In order to be in a position to render the required service, this organization should be provided with an adequate library, stocked with authoritative works on all branches of the subjects dealt with, together with all official publications and reports from Government scientific and technical departments, as well as scientific journals. Official Blue Books of trade returns would also be essential. The publications should not be restricted to the Empire but should include all the more important ones published in foreign countries. All the most important articles published in journals, reports, etc., should be card indexed so as to be readily found when occasion arises. Abstracts should be prepared according to specific requirements and distributed to those interested.

The organization should be familiar with the work carried out in every government department or scientific institution throughout the world, and should be in constant touch with trade interests, so as to be able to assist in the many cases where published information does not touch upon the specific problem. The organization should know what is being done by other bodies and would be in a position when necessary to refer an inquirer to the relevant institution, authority, department or business firm for the latest and best advice.

It would often be desirable for the organization to make certain information available without waiting for it to be asked for. Such general information might well be disseminated by means of a journal issued at regular intervals ; or if the subject is large and important enough a special publication on it might be issued. An additional method of spreading knowledge is by means of lectures given by experts.

In some cases assistance cannot be readily afforded without submitting the material in question to chemical examination or to small-scale technical trials. Such preliminary work could either be carried out in the organization's own laboratories or workshops or the task might be farmed out to some more suitable expert in that particular line.

The organization should be staffed by officers fully qualified and expert in their own particular subjects. Some of them should preferably have had overseas experience in an Empire country or elsewhere. It would be advantageous if facilities were afforded for officers to travel overseas in order to gain first-hand knowledge of the problems with which they are likely to be faced. On the other hand every effort should be made to encourage officers from overseas government departments, etc., to visit the organization in order to exchange views and to discuss the work they are doing. Such personal contact between officers of the organization and officers overseas should not be restricted to those from the Empire. Representatives of foreign countries should also be invited to visit the organization. Such personal contact with officials from all parts of the world is essential for successful collaboration and maximum service.

Care would also be necessary, however, to ensure, wherever possible, that an inquirer for information, such as a planter or a miner, should make use of his local Department of Agriculture or of Mines. It must be emphasized that this organization is complementary to the local

government departments and is not intended to usurp any of their functions.

The organization would therefore serve as a clearing house of scientific and technical information on economic products, but care would have to be exercised that particulars given in confidence were not divulged to the detriment of the interests of those who had been gracious enough to supply them.

Most of the functions described above have for some fifty years been carried out by the Imperial Institute, but the fact that this Institute has been doing so, is not as widely known as it should be. Nevertheless during its existence the Institute has been approached by and has given advice and assistance to every country in the British Empire. In the years before the war some 2,500 inquiries a year were dealt with, and about 700 samples of raw materials were chemically examined in the laboratories.

During the war the accumulated information at the Institute proved of immense value especially to government departments concerned with defence, economic warfare and supply.

The library of the Institute contains one of the finest collections of reference literature on economic products, as well as standard works on agriculture, forestry, geology, mining, metallurgy and on the preparation and marketing of raw materials of animal, vegetable and mineral character. Scientific journals, government reports and other publications, together with statistics of trade returns are regularly received, and the indexing staff carefully card index all the important articles.

The Institute keeps in constant touch with all the government departments at home and overseas in the Empire, and with a number of such institutions in foreign countries. By means of its Advisory Councils and Consultative Committees on which are representatives of technical and scientific bodies as well as of business firms, constant contact is maintained with trade interests and with market requirements.

Half-yearly progress reports are regularly received from certain government departments overseas. These are published in the quarterly Bulletin.

Information is disseminated by the Institute by means of (*a*) reports submitted to government departments and other inquirers; (*b*) the quarterly Bulletin of the Imperial Institute which contains selected reports of investigations carried out, articles, notes and bibliographies of agriculture, forestry, insecticidal materials of vegetable origin and on mineral resources; (*c*) the Annual Statistical Summary of the Mineral Industry, which contains official figures of production, imports and exports of metals and minerals; (*d*) monographs on specific economic products—more than fifty of these have already been published on minerals as well as a number on plant and animal products—and (*e*) miscellaneous publications.

The work could be greatly extended and improved if better facilities for obtaining information could be provided. This could be achieved if it were arranged for certain officers in the Empire abroad to be charged with supplying up-to-date information about developments in their own countries; but at present their numbers are so small that it would be unreasonable to suggest any such additions to their onerous duties. Again,

if trained scientists or economists were attached to consulates abroad they too could be a source of much useful information.

The Institute has acquired a considerable reputation for impartiality in respect of the information and advice it supplies, indeed, in many cases it has functioned as a kind of referee between government and individual or firm. In framing Mining Ordinances, for instance, the Institute's advice is sought by governments so that both the authorities and the mining industries may be fairly protected.

In the laboratories of the Institute the examination and evaluation of raw materials is undertaken as a preliminary to assessing their value and reporting on their potentialities. Small scale technical trials are also carried out on some classes of products such as paper-making materials, essential oil plants, oilseeds, fibres for cordage, and clays for use as bricks and tiles, earthenware, pottery and refractories. In some cases arrangements are made when necessary for such trials to be undertaken by some other experts.

The need for accurate statistical information such as the Institute endeavours to provide, especially for the mineral industry, grows ever more insistent. Its annual Statistical Summary of the Mineral Industry is generally recognized as a standard work of reference unequalled except in the United States. This is a publication which could be greatly improved and made more comprehensive if sufficient staff could be provided for its compilation. But such work is very complex and must be done under the supervision of men trained in the economics of the mineral industry. There is very great need of a more uniform and complete system of compiling statistics of both mineral and chemical industries not only in the Empire but in the whole world. There is also a great need for the collection of statistics of consumption of raw materials, and very few countries attempt to do this in time of peace.

It will be seen from the above brief description of the work of the Imperial Institute, and from the more detailed account given in another paper submitted to the Conference, that in the Institute there already exists a foundation upon which to build a larger organization, whose functions would be to collect from world sources and disseminate to Empire inquirers scientific and technical information on economic products. In the Institute there already exists a small but experienced staff well versed in the work proposed for this organization, and they have at their disposal a considerable library with its complementary card indexing service. It should be possible, if furnished with increased financial support and with an increased staff, to develop from the Imperial Institute with its fifty years experience an organization such as is envisaged above.

MEASURES FOR IMPROVING THE DISSEMINATION OF SCIENTIFIC INFORMATION WITHIN THE EMPIRE, INCLUDING THE DISSEMINATION OF SCIENTIFIC NEWS TO THE PUBLIC GENERALLY, AND OF SCIENTIFIC AND TECHNICAL INFORMATION TO INDUSTRY, AS WELL AS ABSTRACTING AND LIBRARY SERVICES

By D. Cairns, M.Sc.

The improvement of the means of dissemination of scientific information within the Empire is a most vital subject to New Zealand. The geographical isolation of the country, together with its comparative youth from the scientific and cultural point of view, intensifies the need for information. The interchange of personnel with other countries either on a temporary or permanent basis is infrequent, and the lines of communication have been exasperatingly slow in bringing up-to-date knowledge to our shores.

The sense of isolation which New Zealand feels in the scientific world has prompted her to be the pioneer in the field of scientific liaison work. It is pertinent to note that this country established in 1928 a scientific liaison office in London. This has formed a valuable link with advances in knowledge in Great Britain. These liaison links have now been extended to the United States of America and Australia. The actual structure of the liaison offices is the subject of a separate paper. This brief mention serves to indicate the importance of these offices in relation to the dissemination of information both to and from New Zealand.

A central organization has been established in New Zealand to work in close association with the liaison services. This is known as the Information Bureau, and is attached to the Department of Scientific and Industrial Research, Wellington. It is modelled along similar lines to its Australian counterpart in the Council of Scientific and Industrial Research, Australia. The main functions of the Information Bureau are as follows :—

(i) Editing and publishing the *New Zealand Journal of Science and Technology* (monthly).
Editing and publishing the *Industrial Bulletin* (monthly).
Editing and publishing all other publications of the Department of Scientific and Industrial Research, including the annual report, departmental and divisional bulletins, coloured soil and geological maps, etc.

(ii) Provide a centre for the collection, collation and distribution of scientific and technical information received through scientific liaison officers overseas, and other sources. Also to provide the reverse service to overseas inquiries.

(iii) Provide a library service including a bibliographical and abstracting service for the Department and Industry.
(iv) Arrange the release of suitable scientific information through the daily Press, farmers' journals, special brochures, etc.
(v) Dissemination of information to industry through the *Industrial Bulletin* (monthly abstracts) and by answers to specific inquiries.
(vi) Arrange for photostats, microfilm, duplicating, etc., associated with the operation of the above information services.

The centralization of information through these channels has proved satisfactory. Adequate integration has been achieved, and a knowledge of the sources of information available locally and overseas has assisted in answering the problems postulated day by day. It is hoped as staff is trained for this special work to operate a return service to Empire countries.

1. DISSEMINATION OF SCIENTIFIC INFORMATION WITHIN THE EMPIRE

In a study of the methods whereby the dissemination of information within the Empire may be improved, it would seem advantageous to examine critically the present channels through which it flows. These fall into the following groups as far as New Zealand is concerned :—

(*a*) Scientific journals, i.e. the published work available to us either by exchange for our scientific periodicals or by subscription.
(*b*) Interim reports either in typed or cyclostyled form.
(*c*) Information by letter or report from Scientific Liaison Officers.
(*d*) Through the Imperial Agricultural Bureaux including local correspondents.
(*e*) By direct personal contacts through visits or letters.
(*f*) Through membership with research associations in Great Britain.

Considerable improvement is possible in most of the above.

(*a*) Scientific Journals

The whole problem of publication of scientific information by medium of scientific journals requires re-thinking. As editor of the *New Zealand Journal of Science and Technology* the writer is aware of the great increase in the volume of papers coming to hand for publication. In the next few years the position threatens to get out of hand altogether. A more up-to-date method for the dissemination of this information must be evolved. The solution herein propounded by the writer is not original but is the one considered most promising.

In each Empire country a central organization for the reception and refereeing of papers should be set up, with a separate small panel for each subject. Papers after release from the panel should be microcopied and copies of these sent for lodgment in each Empire country. For instance, the Information Bureau, Wellington, would then receive a microcopy of all important papers from Great Britain, Canada, Australia, etc. Card or

microfilm abstracts should also be sent. These abstracts would be circulated to workers in New Zealand and papers of interest could be supplied in complete form from the microcopy. Large libraries of this type of material would take up little space and rapid transport is ensured by air routes. All papers of importance could reach laboratories in New Zealand within two to three months of release. A start should be made on the highly technical specialist papers—general papers offer more difficulties.

Until such a scheme can be put into full operation, the introduction of microcopy, microfilm, and photostat should be gradually brought about.

It is also desirable that, until a more satisfactory scheme such as the above has been brought into operation and scientific information is available efficiently and rapidly, one copy of all scientific journals published in the Empire should be available in a centralized source in each constituent country, irrespective of the other distribution in that country. These should preferably be free copies sent by air mail.

These publications should be received in New Zealand by such an organization as the Information Bureau, Department of Scientific and Industrial Research, Wellington. This Bureau represents scientific interests in New Zealand on a wide scale, and is the medium for disseminating the information to other Government Departments, agricultural colleges, university colleges, industry and private research institutions. The centralized source should have available competent abstractors, and the necessary mechanical devices such as microfilm and photostat apparatus. For the purpose of distributing the information contained in journals around the scientific personnel in various laboratories, the use of the centralized abstracting service is clearly indicated. It has been found in New Zealand, for instance, that the circulation of a single journal around twenty or thirty scientists may take up to two years. This system must be abolished and fast abstracting services built up.

Another point of interest to New Zealand is the abstracting of articles appearing in New Zealand scientific journals by the main abstract journals. Due to delays in transit, these do not appear for many months after the published work has come off the press. Here again it is felt that the microfilm abstract might with advantage be used. These could be sent air mail to the abstracting journal as soon as the page proofs had been prepared and many months of tedious waiting saved. The operation of such a service on an Empire basis would serve to bring New Zealand and other outlying Empire countries into much more rapid contact with scientific developments.

(*b*) Interim Reports

Interim reports have been forwarded during recent years in increasing numbers, largely through Scientific Liaison Officers. These have proved most valuable, and should be continued in the post-war years. They are of obvious value to the New Zealand research worker as the first intimation that work is being carried out on a particular problem, and their use could be extended. All workers interested are immediately placed in touch with new or partially completed projects. Discretion naturally has to be used in certain cases. It is realized that the question of priority of publication is associated with this. With a few possible exceptions, however, most

research institutions could release more information of an interim nature. The use of the Scientific Liaison Officer as a medium for forwarding this type of information is good and should continue whatever the form liaison offices take.

As early as possible an indication should be given as to the source and form in which the final report will be found. Many overseas interim reports in the Information Bureau, Wellington, have most certainly been superseded by final published work, but this is often most difficult to trace. An indication should also be given in the final published report of the interim reports which it supersedes.

New Zealand needs to do much more by way of reverse service under this heading. It is obvious that information is lacking in many Empire countries of the work carried out here. This is only possible because many of the projects are carried on for a number of years before a report of any nature is prepared. If we are to improve Empire information services, this state of affairs must cease.

Information on the down grading of the security classification of a large number of scientific reports issued during war-time is urgently needed in New Zealand. It is obvious that much of this information has now been released for publication and general use, but no official intimation has been forthcoming.

(*c*) Reports from Scientific Liaison Officers

Reports from Scientific Liaison Officers have proved of inestimable value over a long period of years. The choice of a senior scientific officer with wide interests and a thorough knowledge of special local conditions, is essential. The actual manner in which liaison offices will function is the subject of a separate report. As far as information is concerned, their special value lies in the forwarding of advance details of work in progress, and reports on scientific subjects as requested by New Zealand workers. The knowledge of New Zealand conditions, particularly agricultural, is very essential under both these headings. Whatever the final decision as to the operation of scientific liaison offices, their continued existence is fully justified from the New Zealand experience and need.

Again, little reverse service takes place. New Zealand is continually receiving, through liaison channels, excellent progress reports on work overseas. Research workers in New Zealand have not yet realized the importance of publication and their duty to science to disseminate information as widely as possible. If Empire co-operation is to be achieved in this matter, New Zealand has a very definite forward move to take.

(*d*) Imperial Agricultural Bureaux

The Imperial Agricultural Bureaux have provided an excellent service to New Zealand, particularly so in the field of abstracts of literature and reviews of problems relating to our primary industries. The official correspondents provide a personal link with the various Bureaux, but they do not appear to have been utilized as fully as possible. It has been necessary to link their activities with those of the Scientific Liaison Officer on the spot in London in order that the Bureaux may take advantage of

the special knowledge of local conditions the Liaison Officer has. This link is principally by medium of copies of correspondence being minuted for the attention of the Scientific Liaison Officer in London when official correspondents forward inquiries to the Bureaux. The Scientific Liaison Officer represents New Zealand on the Imperial Agricultural Bureaux Council, and it is imperative that he should be fully informed of all inquiries emanating from New Zealand.

The extension of the Bureaux type of organization into the industrial field seems advisable. One of the major difficulties encountered in New Zealand in tapping sources of information on the industrial side is the lack of adequate abstract services in Great Britain. A very great improvement could be effected here with value to all Empire units.

(*e*) Visits of Scientists

Visits of scientists form the subject matter of another paper in this series, but the matter may be briefly mentioned here. This is undoubtedly a most valuable link in the exchange of information, particularly in specialized fields. It is found, however, that personal contacts are not kept alive over long periods, and it is necessary to fall back on other machinery for the procurement of information.

(*f*) Membership with Research Associations in Great Britain

The flow of information to special groups through membership with Research Associations in Great Britain has proved an efficient channel. Much of the information requires special interpretation to fit in with local conditions. This is achieved by personnel linked to the industries concerned.

2. THE RELEASE OF SCIENTIFIC NEWS TO THE PUBLIC

This has always proved a most difficult task, mainly because there are so few with ability to interpret scientific findings in a form acceptable both to the scientist and to the public. Many scientific men of standing scorn the thought of publicity through the medium of the daily press or weekly magazines, yet it is to the people we turn for financial support and to the people we must give an account of the work we do.

The interpretation of research results to the public has been attempted through the Information Bureau, using specially accredited writers. These have been chosen simply for their ability to write scientific information accurately and in an assimilable form for the public. In this way suitable reporters of the daily press have been given access to research results of news interest by personal contact with research workers. These latter have had the opportunity of checking the script before publication. This system has worked smoothly and efficiently. Other information is released in the same manner to weekly magazines, farmers' journals and business papers, in each case the most suitable medium being chosen for publication by an officer of the Information Bureau. From time to time publications of a general nature involving information on a variety of related subjects can be released in brochure form. For example, a topical brochure on garden pests, plant diseases or house-infesting insects may be prepared for release.

the desirability or otherwise of perusing the original paper. A photostat It is emphasized in connexion with publicity that care must be taken that work in its early developmental stages does not reach the Press. Items of interest are also made available to the Press on results of work overseas when these are of wide general appeal.

The other methods of passing information to the general public are lectures, films, and displays. The former method suffers considerably because of the inability of the majority of scientific men to reduce their information to the language of those interested. Much more could be made of those who have this ability and the Empire could benefit from extended tours by prominent scientists able to interpret research work to their fellow-men.

Films and displays are being increasingly used. In New Zealand co-operation has been achieved with the National Film Unit. Releases are made in newsreel form throughout the country. Much more use could be made of films if available. Empire co-operation on the exchange of suitable films would assist in building up a knowledge of scientific development. In this field Scientific Liaison Officers could function more effectively than in the past.

Display work is integrated with industrial fairs, royal agricultural shows and other such special occasions. The relation of scientific work to primary and secondary industries is depicted by means of posters, working apparatus and demonstration. Here again, on occasions of national shows, Empire exhibits showing phases of important research projects should be a feature. Some organization is required to bring this into effect. The outstanding achievements of British scientists have too often been lost to sight because of publicity and propaganda for less meritorious work.

3. SCIENTIFIC AND TECHNICAL INFORMATION TO INDUSTRY

The first essential in supplying scientific and technical information to industry is an adequately staffed information bureau with a full knowledge of how and where to obtain the required data. The personnel side has proved a major difficulty in New Zealand. Scientific Officers with the right personality and a good knowledge of industrial development have proved difficult to locate. The various links with overseas information discussed in 1 (*a*–*f*) indicate that the 'how and where' aspects of information are fairly satisfactorily covered.

Transmitting information to industry is carried out in New Zealand through five principal channels. These are :—

(i) The *Industrial Bulletin.*
(ii) Research associations of groups of industries.
(iii) Scientists attached to the staffs of firms.
(iv) Direct contacts by government scientists in response to requests for assistance (industries not carrying their own professional staff).
(v) Answers to specific inquiries by letter or personal contact.

The first of these methods involves the publication of authoritative abstracts in a monthly publication forwarded to all industrialists in New Zealand. The abstracts are sufficiently informative to indicate to the reader

service operates to satisfy the demand in this respect, and a thoroughly integrated library service (to be described later) assures the industrialist access to all the literature available on a given problem. In most cases the problem is linked to the research officer specialist in the particular work, and a further opportunity is thus given for contact between science and industry. As mentioned earlier in this paper, the lack of a complete abstract service of industrial progress in Great Britain is often a severe handicap. Greater Empire co-operation on this front would be beneficial to all.

The second and third methods of disseminating information to industry are probably the most successful. Scientists engaged for work with research associations of industries, and those operating within the framework of specific firms, are able to apply information much more effectively. The detailed knowledge of factory processes enables them to eliminate a great number of possible difficulties when faced with a problem, and concentrate on the one or two unknowns. A professional officer approaching the same problem from outside the industry is at a distinct disadvantage. Encouragement has been given in New Zealand to the development of research associations of industries, and, where possible, the placing of scientists in industries.

The fourth and fifth methods of applying information although less effective than the previous two, are nevertheless important. There has been a major development in assistance to industry through the establishment of the Information Bureau, linked with the facilities of the Scientific and Industrial Research Department. Although still in its early stages it is obvious that a very real answer to the problem of getting information to industry has been found.

4. ABSTRACTING AND LIBRARY SERVICES

Library services in New Zealand have recently been co-ordinated through a National Library Service. Through the National Library Service all libraries—government, municipal and learned societies—operate an interloan service free of charge. No centralization has been attempted, simply integration of existing services. A book resources committee under the control of the New Zealand Library Association, ensures that at least one copy of all important works is available in New Zealand. A recent development under the National Library Scheme has been the establishment of a Technical and Commercial Library Organization, including an information service linked with existing scientific and technical information offices. It is thus possible in New Zealand to visualize a thoroughly integrated service in which all sources of information existing in the country are linked. A number of the libraries have membership with A.S.L.I.B. and Empire co-operation on the lines of this organization will ensure that outlying areas such as New Zealand will suffer no handicaps.

Abstracting services in New Zealand are in their infancy. It is hoped to establish the scientific abstracting services in the Information Bureau, Wellington, and technical abstracting services in the Department o Industries and Commerce, Wellington, and National Library Service.

DISSEMINATION OF SCIENTIFIC INFORMATION AMONG RESEARCH WORKERS AND DEPARTMENTS

By Sir DAVID CHADWICK, K.C.M.G., C.S.I., C.I.E.
(Secretary to the Executive Council of the Imperial Agricultural Bureaux)

1. The relevance of this paper lies in the fact that these twelve bureaux, together with the slightly older Bureau of Hygiene and Tropical Medicine, have been specifically formed by the governments of the Empire jointly for, amongst other purposes, the collection and dissemination of scientific information. That is their chief duty. They are financed by all governments in an agreed manner. Each has its fairly well defined field but the twelve agricultural bureaux work as an inter-related group under one Executive Council, which is composed of representatives of the participating governments. They are thus in the truest sense co-operative ; co-operative officially in their finance, administration and definition of their activities, co-operative in execution between themselves.

2. Each was formed following a decision or recommendation of a fully representative Conference ; thus those of entomology and mycology followed from decisions at Imperial Conferences, eight of the bureaux from recommendations of the Imperial Agricultural Research Conference of 1927, and the two others (forestry and dairy) from those of the British Commonwealth Scientific Conference of 1936.

3. The purpose of each one of them is to be an effective clearing house in its own branch for the interchange of information of value to research workers in agricultural science throughout the various parts of the Empire. The functions of a bureau, as defined in 1928, are set out in the appendix. The two oldest ones, entomology and mycology, also assist in the indentification of insects and fungi. They are equipped for that purpose and styled institutes. The discharge of the functions as laid down in the appendix presupposes close and direct relations between the officers at a bureau and those specialists in Empire countries it is the primary function of that bureau to serve. For the regular dissemination of the information it collects each bureau has, in fact, started and now publishes its own *Abstract Journal*, and the bureaux severally or jointly publish reviews of information on particular subjects which they know or learn are of general and immediate interest. But whilst these publications are the chief tools of the bureaux for the systematic dissemination of information, their compilation and issue is not the sole purpose and 'end all' of the bureaux. Their work is not approached from a strict library standpoint. Their purpose is to develop close touch with those whom they primarily serve and to strive to learn and meet their needs.

4. The branches of science and their application to agriculture, livestock,

forestry and nutrition, with which these twelve bureaux severally deal, the dates they were formed, and their locations, are as follows :—

entomology	1913	South Kensington, London
mycology	1920	Kew, Richmond, Surrey
soil science	1929	Rothamsted
nutrition	1929	Aberdeen
animal breeding and genetics	1929	Edinburgh
animal health (veterinary)	1929	Weybridge
plant breeding and genetics	1929	Cambridge
pastures and forage crops	1929	Aberyswyth
horticulture and plantation crops	1929	East Malling
agricultural parasitology (helminthology)	1929	St Albans
dairy science	1938	Shinfield, Reading
forestry	1939	Oxford

5. Specialists from overseas are more likely to visit research institutes well known in their own branch of science, than central libraries. Each bureau has therefore been located at such an institute, but is *not part* of it. By this means bureau officers should be helped both in keeping in touch with current trends of scientific thought in their subject and in meeting and getting to know research workers interested therein. On scientific matters each bureau is encouraged to correspond direct with scientists. No bureau puts out its information under the general anonymity of the organization—' the Imperial Agricultural Bureaux.' Each does so as the ' Bureau of . . . .' of which ' Dr . . . .' is Director. The responsibility for what is issued is clear. It is also believed that scientists prefer to know the names of those with whom they correspond. It is believed that the usefulness of a centre of scientific information should be judged by the extent to which it serves the needs of a fairly clearly defined group of men, scientists and those with scientific training, and the confidence it inspires among them. To earn such a verdict is the hope. To do so means that quality of work must be attained and maintained, continuity assured and response to the development and changing emphasis of scientific thought forthcoming.

6. Each bureau has a director, a specialist in his subject with some languages, and a few assistants either scientists or linguists or both. Attempts are made to enable directors to visit countries overseas, but such opportunities are limited by finance, pressure of work, shortage of staff and latterly war.

7. The bureaux—see their titles—do not follow the academic divisions of the sciences, but the manner in which, in general, scientific research is applied to agriculture. The object once more is to try to keep in view the needs of a fairly clearly defined group in each case, and although all the bureaux follow the same general lines of work it may well be that some bureaux are more strictly scientific in their outlook than others, and that the same paper is noticed in two journals from different standpoints. An attempt is made to keep the numbers of the various journals of a form and size that the recipient is likely to look through and read rather than place them directly on the shelves for later reference. Scientific facilities vary

greatly in the countries of the British Commonwealth. Abstracts as a rule are of the informative rather than of the indicative type.

The bureaux do not touch clinical, economic or social information or general statistics ; but having been added to from time to time at the instance of departments to meet their needs, they now cover, not all, but most of the range of the natural sciences in their application to agriculture, etc.

8. Science tends constantly to increasing specialization. Its application to the needs of man repeatedly calls on the expert knowledge and experience of different branches of science. There is a conflict of tendencies. Obviously

(*a*) for administrative reasons, centres of information conceived on the plan of the bureaux cannot be multiplied indefinitely to meet the particular needs of every possible group however small

(*b*) though efforts are made to serve the needs of fairly defined groups some scientists whose interests have spread into cognate fields should at times refer to more than one *Abstract Journal*

(*c*) though the applications of science to the needs of man are, for departmental reasons, conveniently looked on as agricultural, medical and industrial, those terms as regards the natural sciences themselves have no meaning. Science as such cannot be departmentalized. Whilst looking to the needs of those whom they have primarily to serve, centres of scientific information, if they are to serve those needs adequately, should and must be encouraged to work together and even join in common effort on the borderlands where both have something to contribute either to meet the needs of their own groups, or the needs of special groups.

9. Within the bureaux this co-operation is sought by having them all as a group, with consultation among them. Frequently two or more bureaux co-operate in producing a review of information on some subject. They are not isolated units. But such co-operation goes and should go further. For instance much of the basal science underlying nutrition is the same whether for animals or man. With the co-operation of the Medical Research Council, and the full approval of the British Commonwealth Scientific Conference of 1936, *Nutrition Abstracts and Reviews* covers both human and animal nutrition. Of its 1,300 subscribers probably more are interested in human nutrition than in animal nutrition.

Again, the Imperial Mycological Institute issues jointly and in co-operation with the Bureau of Hygiene and Tropical Medicine an *Annotated Bibliography of Medical Mycology* for those working in that specialized field.

10. One word on administration. The bureaux are subject to all governments equally and not to any one department of any one government. Governments have laid down certain general principles which must be observed by agencies so organized, of which the bureaux was the first. They are

‘ (*a*) The complete constitutional equality of the participating governments should be recognized in the method of appointment to, and composition and organization of, each agency.

'(*b*) The formal instrument appointing persons as members of inter-Imperial agencies should be issued by each government concerned.

'(*c*) Adequate financial provision should be forthcoming. This implies not only sufficient funds but also a reasonable certainty of income over a definite period of years.

'(*d*) At the same time, there should be careful and periodical examination of the various institutions at Empire conferences suitable for the purpose, as without this assurance governments can hardly be expected to provide financial support as visualized in (*c*) above.

'(*e*) The management of inter-Imperial agencies should in no way be subject to financial control by the Finance Department of any one government of the Commonwealth, but over and above regular scrutiny by a suitably constituted finance committee, they should be free to take advantage of the experience of such departments.

'(*f*) Each inter-Imperial agency should approach the participating governments directly through the appropriate channel.'

Experience has been gained in applying these rules.

At the 1936 Conference Dr P. J. Viljoen (South Africa) put the position thus : 'We, here, are all partners in the same scheme. It is our own show. It is not a United Kingdom organization. It is not a matter of contributing and of meeting, but of developing the feeling of having your own particular machinery, not having anybody else's. That is the spirit and that is important.'

11. Bureau publications are for specialists. Some journals are monthlies, others quarterlies. Despatches of all publications in 1945–46, journals and reviews, numbered 80,000 of which 70 per cent were sales.

APPENDIX

(Extract from 'The Scheme' accepted by governments—1928)

THE IMPERIAL AGRICULTURAL BUREAUX

The purpose of Imperial Agricultural Bureaux is to act as effective clearing houses for the interchange of information of value to research workers in agricultural science throughout the various parts of the Empire, and for this purpose they should discharge the following functions :—

A. Collection of information

(i) A bureau should maintain an index of research being carried out in different parts of the Empire and as far as practicable in foreign countries.

(ii) A bureau should begin by collecting, abstracting, and collating information from all sources bearing on the most important problems under investigation in different parts of the Empire ; but care should be taken to avoid the collection of uncorrelated data.

(iii) A bureau should keep itself informed of the general progress of research work within its province in different parts of the Empire.

(iv) A bureau should in appropriate cases summarize available statistics where these are of importance in connexion with its work.

B. Distribution of information

(i) A bureau should supply, on request, information within the scope of its work to officials and advisory officers. in all parts of the Empire. Where a bureau is not in possession of such information it should endeavour to put the inquirer in touch with the best source.

(ii) A bureau should supply, where feasible, to research workers in the Empire, on request, information including bibliographies and photostat prints of articles on specific problems.

(iii) A bureau should issue information along such lines as may be deemed desirable by the Executive Council.

C. Publication

The general distribution of information (apart from the distribution of information to particular individuals) is part of the duties of a bureau, but the publication of special monographs should only be made with the approval of the Executive Council, and though in many cases it may ultimately be found desirable to establish a journal such publication should not, on account of its permanent cost, be undertaken until the bureau has become fully established and then only on the authorization of the Executive Council.

D. General

A bureau should not undertake any laboratory or field research work involving expense but, in addition to its main function of facilitating the exchange of information, a bureau will be in a position to be of service to research workers in various ways and especially along the following lines :—

(i) by facilitating exchange of workers, especially by supplying information in regard to centres between which exchange would be most profitable

(ii) by facilitating, through correspondence or otherwise, meetings at the most convenient centres of workers interested in the same problems in different parts of the Empire

(iii) by facilitating the exchange of experimental material for research purposes between institutions of workers in different parts of the Empire

(iv) by supplying information on the best centres for postgraduate study, the best sources of supply of apparatus or equipment and any other such information of a general character which might be of service to institutions or individual workers.

THE DISSEMINATION OF SCIENTIFIC INFORMATION IN INDIA

By Sir LEWIS FERMOR, O.B.E., F.R.S.

PROPOSALS for improving the publicity of science in India assume that the present publicity is inadequate. Publicity in science includes two aspects :

1. Publication for the benefit of scientists in India and abroad of the results of scientific research in India.
2. Publication for the benefit not only of scientists but of the general public of India of the results of scientific research and its technical applications both in India and abroad.

1. *Publicity for the benefit of science in general of the results of scientific research in India* seems to be adequately covered by the existing facilities provided by the journals of academies and of specialist scientific societies, and by the memoirs and records, etc., of Government scientific departments and of universities. In addition the correspondence columns of the two monthly journals *Current Science* and *Science and Culture* provide an outlet for scientists to announce discoveries in advance of publication of full results, an outlet similar to that provided by *Nature* in England. The annual publication *Indian Science Abstracts* published by the National Institute of Sciences of India serves the useful purpose of providing a summary of all scientific work relating to scientific research in India. This last publication has fallen into arrears during the war, partly for lack of sufficient funds and partly because of difficulties of staff and paper caused by the war. Now that the war is over and the National Institute is being more liberally provided with funds these difficulties will be overcome. Finally, the annual sessions of the Indian Science Congress Association provide an excellent forum in which scientists of the whole of India can and do gather to exchange views and record advances.

2. *Publicity for the benefit not only of scientists but also of the general public of the results of scientific research and its technical applications both in India and abroad.* We may first notice the two monthly scientific journals. *Current Science* is a monthly journal on the lines of *Nature* founded by the Indian Science Congress Association and edited and published in Bangalore. This journal appeals mainly to scientists but often has editorials and special articles both on scientific and technical matters that should appeal to the general public. I gather that it is intended to convert this journal to a fortnightly issue in the near future and ultimately to a weekly. A greatly increased circulation will increase the usefulness and publicity value of this journal.

Science and Culture is a monthly journal edited and published in Calcutta by the Indian Science News Association. It is akin rather to the former English journal *Knowledge* and its present descendant *Discovery*, both in its

format, and in its more popular appeal as compared with *Nature* and *Current Science*. It publishes numerous articles of a semi-popular nature on the economic, industrial and political aspects of science, and on general scientific advances made throughout the world. It merits a greatly increased circulation.

Further the new Department of Scientific and Industrial Research issues a monthly journal called *Journal of Scientific and Industrial Research*, now in its fourth year. This contains not only valuable articles of the nature covered by its title but lists of patents.

The above journals afford publicity to all branches of scientific and industrial research. There is also the possibility of providing information to the public at large concerning special sections of scientific and technical effort. Thus the Imperial Council of Agriculture Research issues a monthly magazine called *Indian Farming*, whilst the Geological Survey of India proposes to publish a semi-popular quarterly journal *Indian Minerals* specially to disseminate information on all points of view in the mineral industry such as geology, oil, mining, metallurgical treatment, marketing, etc. Should this latter experiment prove successful other branches of scientific and technical activity will doubtless follow suit.

All such journals as those of the types mentioned above will of course reach only those who subscribe to them or who visit libraries and institutions that receive them. They will not normally reach the wider public that does not subscribe to journals covering special spheres of activities.

The Government of India, however, publishes a fortnightly journal entitled *Indian Information* now in its eighteenth volume. This journal contains articles covering most phases of human activities and has a very wide circulation. Some numbers, therefore, contain articles dealing with scientific and technical progress. It might be a good thing if a section of this journal were reserved to such matters so that scientific and industrial progress were constantly (i.e. in every issue) brought before the public at large. The information for such a section could be provided by the Director of Scientific and Industrial Research collaborating with the National Institute of Sciences in India. The alternative to such a proposal might be the institution in India of a monthly bulletin of the newsletter type analogous to the science newsletters issued by the United States Office of War Information. Such newsletters would, however, probably not reach such a wide publication as *Indian Information*.

In writing this note I should not like it to be thought that the general public in India has less opportunity for being informed in scientific and technical matters than the general public in Britain. My impression is that over a considerable series of years the Indian daily press as a whole has shown more interest in scientific and technical progress than is commonly shown by the daily press in Britain. It is not uncommon, for example, for an Indian newspaper to have an editorial article upon the report of a scientific department or a meeting of a scientific society. It is not often that even the leading papers of Britain provide such a service. The Indian newspapers also record the meetings of scientific organizations in India more frequently and at greater length than is usually done in Britain.

MUSEUMS AND EXHIBITIONS

A Paper prepared by the Museums Association

Introduction

The Museums Association in its memorandum ' Museums and Art Galleries in the Post-War World,' presented to the Government in 1945, has already laid emphasis on the need for the provision of circulating exhibitions of a scientific nature analogous to the art exhibitions which have been available for many years to art galleries through the Victoria and Albert Museum and commercial agencies or, more recently, through the British Institute of Adult Education and the Arts Council of Great Britain. The Association therefore cordially welcomes the suggestions made in the paper on ' The Dissemination of Scientific Information to the Public,' and particularly the proposal to set up an Institute of Scientific Information which might, as one of its functions, undertake the organization and circulation of authoritative exhibitions relating to scientific discovery.

Background

The great majority of the museums in Great Britain came into existence in the nineteenth century as a direct consequence of the great surge of scientific discovery and the call for popular education of that period. In the development of their scientific departments these museums were strongly biassed towards the natural sciences. Extremely few museums attempted to deal with the physical sciences or with the applications of science to industry, and certainly none in this country made any attempt to consider the social implications of scientific research, though a few European and American ones have done so in more recent years. This bias towards the natural sciences owed its existence to a number of factors. The work of Darwin and Huxley caught the public attention by the controversies it aroused in pulpit and press, while the discoveries of the great physicists and chemists were perhaps accepted with less public resistance because of their more obvious applications to the flourishing and rapidly expanding industries of the country. More powerful factors, however, were the ease with which material for exhibits of natural science could be obtained and displayed, and the low cost of its installation in museum cases, as opposed to the difficulties of collecting and displaying in an intelligible manner the materials that would illustrate the physical sciences, and the high cost of their installation and maintenance. The net result of this was to cause a fixation of purpose in scientific museums, and to introduce a static feature into their galleries that has caused them to lag behind the newer and more active educational agencies.

Furthermore, while the scientific research of the nineteenth century was, in the natural sciences, concerned broadly with systematics, and in the physical sciences with the molecular structure of matter, its results were

relatively easy for the normally intelligent person to understand. During the last half-century research has become much more complex and highly specialized, so that it is not only more difficult for the general public to appreciate, but also infinitely more difficult for a provincial museum, with its usually limited staff, to aid the public to any greater degree of understanding, while at the same time the need for that understanding has, with each new discovery, become the more urgent.

Present position

It is obvious that the museum can nevertheless take its place on equal terms alongside the other agencies detailed in the paper, and indeed provide methods of approach to this problem that are peculiar to itself, in that the museum relies primarily on the visual presentation of its story while, with the very notable exception of the Royal Institution discourses in which actual experiments are demonstrated, the other agencies rely entirely on the spoken or written word, or the photographic image. If a museum can combine the art of the window-dresser with the accuracy of the scientist in presenting the principles of science to the public, and if it can further keep abreast of the most recent scientific research and interpret it in terms of its social and economic implications, then that museum will be fulfilling a very proper function, and will be taking its appropriate place as an agency for the dissemination of scientific knowledge.

It should, however, be realized what difficulties at present stand in the way of the great bulk of museums undertaking such work. If one excepts the great national institutions, e.g. the British Museum (Natural History), the Science Museum, the Geological Museum, the Royal Scottish Museum and the National Museum of Wales, there are probably not more than half a dozen fully departmentalized museums, with specialized staffs in charge of each section, in the provinces. Which means, in effect, that in each of the 800 other museums the professional staff, varying from one to three or four, must attempt to deal not only with the natural and physical sciences but also frequently with archaeology, local history and even the fine arts.

The provincial museums are, moreover, usually under the control of the local government authority, and their maintenance is a permissive and not a statutory obligation. No grant-in-aid is received by the local authority from governmental sources for their maintenance, the cost of which falls entirely on the rates of the town where they are situated. It follows that the museum must be content with a proportion of such funds as are available after the statutory obligations of the authority have been met, and that consequently few museums, except those in the largest cities, have funds adequate to meet the cost of a changing series of scientific exhibitions on anything like the scale of those organized by the Science Museum. Yet a scheme of circulation which confined its exhibitions to cities of a population of, say, 500,000 and over would be doomed to failure by reason of its inadequacy to reach the greater part of the public scattered throughout the country. Any scheme of travelling exhibitions must take into account the museums in the smaller towns with their slender resources, small staffs and restricted exhibition space.

There is at the present time a further difficulty to be faced arising out

of the destruction of, or serious damage to, a number of the larger museums during the recent war. Thus the museums in Glasgow, Liverpool, Leeds, Hull, Bristol and Birmingham all received more or less serious damage which will impair their efficiency for perhaps ten years to come.

Suggestions

Having presented this outline of existing conditions the Association desires to put forward the following comments and suggestions on the scheme under consideration :

1. From the standpoint of the individual museum

(*a*) Museum collections are now normally divided into exhibited series, and reserve collections available only to bona fide students. It would be necessary, under the scheme, to free a further part of the exhibition galleries for temporary exhibitions, and to recast in many instances the remaining more permanent exhibition. Such a course would probably be welcomed by most directors.

(*b*) The permanent exhibits should serve to demonstrate fundamental principles of science, while the temporary exhibits should call attention to new discoveries of pure science, recent applications of older discoveries and the social implications of these discoveries.

(*c*) In presenting these features to the public the museum should be in a position to call on the other agencies included in the scheme for aid, by way of specialist scientific advice, contacts with research institutions for aid in the supply of materials, the supply of suitable films, the provision of lecturers who could speak with authority yet at the same time simply and convincingly, the provision of press and other publicity (e.g. mention of exhibitions in B.B.C. regional news broadcasts).

(*d*) In the case of the smaller museums technical aid might be necessary in the setting up of exhibits. It is believed that this could be most readily provided through the establishment of certain of the larger museums as centres from which staff and materials might be sent to the smaller ones in the area.

(*e*) Adequate financing would be essential to the proper working of the scheme. It is unlikely that without government aid any serious approach could be made to its full working by the great majority of museums.

2. The Museums Association

(*a*) The Museums Association is in close touch through its office in London with all museums in the country, and would be able to give advice and assistance in the planning and circulation of travelling exhibitions throughout Great Britain and Northern Ireland.

(*b*) The Association would appreciate the opportunity to nominate a delegate to the forthcoming Royal Society Empire Scientific Conference, and to present in more detail its suggestion for bringing museums into the proposed scheme.

(*c*) Should an Institute of Scientific Information eventually be set up, the Association would be glad to assist in any way consistent with its constitution.

3. The proposed Institute of Scientific Information

It is suggested that, in relation to museums, an institute of this type should be equipped to provide the following services :

(*a*) A periodical publication designed to provide authoritative information regarding the outstanding results of recent scientific research, and calling attention to certain aspects of the work that might form the subject of exhibitions.

(*b*) The organization and circulation of travelling exhibitions at a reasonable cost to museums in all parts of the country. As a guide it may be stated that the total cost to an art gallery of hire, transport and publicity for an art exhibition circulated by the Arts Council rarely exceeds £15–20 for one month, while one circulated by a commercial agency does not usually exceed £25–30.

(*c*) The provision of specialist advice on the content of exhibitions, both temporary and permanent.

(*d*) Liaison between museum, research institutions and manufacturers whereby technical advice and the loan or gift of material for exhibition might be provided.

(*e*) A library of carefully selected scientific films, available to museums at a reasonable cost.

(*f*) The publication of attractively produced and authoritatively but simply written handbooks to accompany travelling exhibitions, and to be on sale in the museum.

(*g*) The institute's resources should be available not only in connexion with the travelling exhibitions, but also to any museum arranging its own series of permanent or temporary exhibitions, some of which might well be of special local interest, e.g. the work of textile physicists in the West Riding of Yorkshire.

MEMORANDUM ON SCIENCE ABSTRACTS

By Sir CLIFFORD PATERSON, O.B.E., F.R.S.
(Chairman, Management Committee of Science Abstracts)

MANAGEMENT

Science Abstracts is a monthly publication, covering the fields of physics and electrical engineering, which has been issued under the joint auspices of the Institution of Electrical Engineers and the Physical Society (London) since 1898. It is guided by a Committee of Management consisting of representatives of these two bodies and of the Royal Society, and is operated in close association with the American Physical Society and the American Institute of Electrical Engineers. The publication is the property of the Institution of Electrical Engineers which conducts its preparation and publication and whose Council makes an annual grant to its finances.

SCOPE

The publication appears in two sections, A (physics) and B (electrical engineering). It is designed to keep the working scientist and engineer in close touch with current progress. Therefore, the policy is to cover a wide cross-section of material extending, in the case of section A, from the border-line realm of mathematics on the one hand and physical-chemistry and bio-physics on the other, and includes astronomy, crystallography and geophysics, as well as all branches of physics. In the case of section B it is the policy to cover the realm of all the mechanical sciences with which electrical engineering is concerned, including in particular power engineering, machines, radio, telecommunications and electronics.

CONTENTS AND CIRCULATION

At present paper restrictions limit the number of abstracts to 200–300 per month in each section, drawn from over 200 British, American or other foreign periodicals, and the two annual volumes thus contain about 6,000 abstracts, for which author and alphabetical subject indexes are provided. European scientific journals published between 1939 and 1944 are now being abstracted as they become available. During the year 1945, 1,483 copies of *Science Abstracts* were issued per month to members of the Institution of Electrical Engineers, 5,919 to members of societies collaborating with the Institution, including 4,087 copies distributed in the U.S.A. and 2,072 to the public (total circulation, 9,474).

COLLABORATION WITH *British Abstracts* (PUBLISHED BY THE BUREAU OF ABSTRACTS)

Since 1943, when the Royal Society urged that steps should be taken to secure closer co-ordination of scientific abstracting services, a number of

informal meetings have taken place between representatives of *Science Abstracts* and of the Bureau of Abstracts (which deals with physiological and chemical abstracts) to discuss means whereby duplication of labour in abstracting articles of common interest to both services might be reduced and the range of journals scrutinized extended. There has also been consultation at an editorial level resulting in the employment of abstractors whose work is common to both publications, and the provision by each service to the other of various journals (or in some cases, actual abstracts) which had hitherto only been available to one.

It is the view of the Committee of Management of *Science Abstracts* that it would be desirable for these two existing publications to approximate in format as much as possible.

Representatives of the two organizations have recently reviewed the question of co-ordination and the following resolutions drawn up at a joint conference held early this year have now been adopted by the two bodies.

Resolutions

(*a*) Whilst looking forward to the time when there will be a larger measure of integration in the spheres of scientific education, the Conference suggest that it is necessary to maintain at least two abstracting services each with a particular bias in the special fields of science covered by each service.

(*b*) The Joint Conference regret the necessity for this partial duplication of abstracting effort and look forward to the time when such differentiation can be obviated.

(*c*) The Joint Conference recommend to the Committee of Management of *Science Abstracts* and to the Board of the Bureau that a Standing Joint Consultative Committee be set up to study the possibility of further collaboration and co-ordination of work, and moreover suggest that this Committee consist of five delegates from each organization, together with the representative of the Royal Society who is for the time being a member of the Committee of Management of *Science Abstracts*. Each body to have the right to have in attendance at meetings such officials as it may consider necessary.

(*d*) The Joint Conference suggest that one of the first duties of the new Consultative Committee be to devise such mechanism as would further the co-operative work of the two bodies and at the same time to suggest means by which other bodies interested in abstracting might be co-opted.

Universal Decimal Classification

Each abstracts publication has its traditional structure and objectives to which its readers have become accustomed. It improves these from year to year under advice from users and abstractors and there is no proposal for an early or sudden unification of the two publications. For instance, *Science Abstracts* bases the grouping of its subject matter upon the Universal Decimal Classification. This has certain admitted disadvantages but its use is favoured by a big majority of its readers. Enthusiasm, how-

ever, for the application of this system is not shared by those responsible for working in some other fields of science for which they consider the Universal Decimal Classification as unsuited.

Whilst, therefore, this classification is the only widely recognized international system of its kind, it would not seem desirable at this stage to seek to press all abstracting into the same mould but rather to accept that each publication must evolve its own character, provided that it has and uses the advantage of exchange of experience and collaboration with the abstracting agencies which serve other fields of science or technique.

For the benefit of those who desire to use the Universal Decimal Classification it is suggested by the management of *Science Abstracts* that the Empire Conference of Scientists might be invited to urge the more general consideration and study of this system and to emphasize to those responsible for the management of the U.D.C. the need for its more active and continuous review in the light of experience and as scientific knowledge and practice advances.

MEASURES FOR IMPROVING THE DISSEMINATION OF SCIENTIFIC NEWS TO THE PUBLIC GENERALLY AND OF SCIENTIFIC AND TECHNICAL INFORMATION TO INDUSTRY, AS WELL AS ABSTRACTING AND LIBRARY SERVICES

By Sir DAVID RIVETT, K.C.M.G., F.R.S., D.Sc.
(Chairman, Council for Scientific and Industrial Research, Australia)

As far as ' the public generally ' is concerned, one may wonder which is the more undesirable of its two current attitudes of mind ; complete indifference to scientific achievement based on total ignorance, or a fearful faith connecting science with atomic bombs and miracles.

Obviously what can be done with the public depends largely upon the standard of education of the masses composing it ; and I suspect that nowhere in the Empire have we great occasion to congratulate ourselves upon the educational stage to which we bring, and at which we leave, the huge majority of our young people. Possibly picture-shows offer the best opportunities for spreading knowledge. The Americans sometimes do this sort of thing uncommonly well, at other times they fail pathetically. There is certainly an opening here for the British film industry, particularly if it seeks the help and advice of professional educationalists.

The passage of scientific and technical information to industry is quite another matter, not without its own complications. The variation amongst intended recipients is in itself a problem which prevents generalization. In Australia, for example, you may find two pastoralists on adjoining properties, one keeping up to date in his reading and in his practice with the best knowledge on pasture improvement in his region ; the other ignoring even the evidence before his eyes when he looks over the fence. On the other hand, in the irrigation areas of the Murray and Murrumbidgee River systems, the settlers (growers of fruits of all kinds, vegetables, etc.) are as a whole so keen and eager that our research station staffs often complain that new ideas, while still under examination, are seized upon by the farmers and put into practice long before a sound verdict on their correctness has been secured.

With us, too, the position is rendered very difficult by our political constitution so far at least as the primary industries are concerned. One need not go into any detail of the difficulties of working a federal system of the type under which we labour. The point is that it has been necessary to make a rather sharp division between the responsibilities of the Commonwealth Council for Scientific and Industrial Research and those of the State Departments of Agriculture. It will be sufficient to say that the former body has agreed to leave the fields of demonstration and extension work entirely to the latter. Therefore the successful passage to

the men on the land of knowledge gained in C.S.I.R. laboratories and field stations depends largely upon the familiarity of State Department officers with such knowledge. It is an indirect passage, and the results are inevitably variable. There is, of course, direct contact between investigators and practical men through publications ; but the written word is never as effective in agriculture as the spoken word and the practical demonstration.

In secondary industry in Australia there is no such intermediary, and one may deal more directly with the problem. No solution is yet available but, broadly speaking, we in C.S.I.R. are convinced that the research man should not be called upon to act also as the extension officer. Further, we know that the latter will not be successful unless he himself has personally spent some time in research laboratories, and then maintains his contact with them after he has transferred to the rôle of teacher.

We think we shall find it essential to maintain two separate staffs for the two lines of work. If so, then it will be well to recruit the disseminators of technical information from the ranks of the producers of it.

It is a familiar fact that most research workers outlive their essential function. Some lose their curiosity at twenty-five and few have it in very vigorous form after forty ; some never lose it. At whatever stage the fading begins, a man may, with advantage both to the research laboratory and to the extension field, be transferred to the latter, provided that he possesses in sufficient degree the normal essentials of a purveyor of knowledge by precept and practice.

In secondary industry the position with us is often far simpler than it is on the primary side. Collaboration with a works possessing a capable scientific staff of its own, in touch with, or maybe recruited from, scientific laboratories, is easily effected. Such places do not come to national laboratories with their day-to-day housekeeping difficulties. They are able, and prefer, to handle them themselves. Where the national organizations (including universities) come in is in tackling problems of wide general significance and common interest to all members of the industry. It is not difficult to find many urgent enquiries to the cost of solution of which big (competitive) companies are willing to contribute, and where no demand for secrecy or any limitation on publication of results, let alone requests for patent cover, will be made. One could quote many examples from Australian experience.

Smaller businesses not employing scientific aid (or perhaps incapable of appreciating its value to them) will continue to seek help, or at any rate to need it, on hosts of minor matters the investigation of which represents a comparative waste of time and effort for a highly trained staff. There is probably no single satisfactory way of handling such cases.

As to abstracting and library services, they present a problem that presumably will always be with us. All I wish to say is that we in the Australian C.S.I.R. have felt compelled to set up an Information Service (which is directed by the secretary to our present delegation, Mr J. E. Cummins) which, with a staff now grown to some thirty people, endeavours to cope with all those enquiries which pour in and are capable of being handled on a basis of existing knowledge available in scientific literature. It might be well for those delegates who are particularly interested in such

work to meet and compare notes, particularly as this is a line of scientific activity in which individual units of the Commonwealth might develop great mutual usefulness.

We have found two aids to be essential to the success of information work. One is the maintenance of an up-to-date catalogue of all scientific periodicals in the libraries of Australia, whether they belong to Commonwealth or State Governments, universities, scientific societies, professional institutes or industrial firms. This is a bigger task than it may seem at first glance, but once undertaken, it will not be dropped. The other aid is the setting up of photographic establishments at selected centres in which photostatic copies of any desired articles can be made at short notice and at low cost (say, 1d. to 2d. per page). Any library will make its volumes available for use by the appropriate authority, while the sending of large volumes on loan to borrowers who wish to read one particular paper is entirely obviated.

THE DISSEMINATION OF SCIENTIFIC INFORMATION TO THE GENERAL PUBLIC

A paper prepared by a working party under the chairmanship of Sir RICHARD GREGORY, F.R.S.

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HISTORICAL INTRODUCTION

In this paper we are concerned with the dissemination of scientific information from the original sources of knowledge to the general public. In particular we shall deal with films, broadcasting, the Press and exhibitions. We shall not, in this paper, be concerned with special library services, abstracting, indexing or microfilms, because these are more the concern of scientists themselves than of the general public. Neither are we concerned with the relations between science, industry and agriculture, which are examined in separate papers for the Conference.

A broad historical perspective will be of assistance in developing the point of view to be adopted in this paper. It will help to show how a discussion of the subject is of particular interest at the present time, and will emphasize the fact that the relation between science and the public has been affected by changes in the nature of both. It is worth while to define these changes in general terms before considering any particular media through which science is popularized, or any recommendations of an administrative kind that may be made in regard to them.

It is sufficient to consider four periods in regard to our subject :

(1) The first is that of the great scientific educators, Davy, Faraday, Tyndall, Huxley, Darwin and Ball, a period that reached its peak shortly after the middle of the last century. The world of that period was one in which the scale and kinds of scientific discovery lent themselves well to the art of the great individual lecturer and teacher. Demonstrations could be made popular, because the principles to be explained were not hard to comprehend and because their implications for practical living were clear. Few intellectual demands were made of the public, whose curiosity was aroused by the magnetism of certain personalities and by the bearing of their message upon the world of visible things. Moreover, the impact of such exposition upon the popular intellectual foundations of the ecclesiastical order was such as to stimulate a kind of controversy in which few could fail to be interested at one point or another. At the same time the utilitarian philosophy and the violence of the industrial revolution, with its forward-looking, aggressive tempo, combined to sustain an optimism about science that was romantic, materialistic and unquestioning in its vitality.

It can scarcely be denied that this romantic optimism about science has been as much a part of the emotional equipment of revolutionaries and reformers as of the leaders of the civilization they sought to overthrow or transform. For this reason alone, a proper treatment of the dissemination of scientific information to the lay public to-day is cardinal to harmonious relations in a world whose various parts are at different stages of development in the transformation of the social order.

(2) During the second half of the century science became more complex, and greater demands were made upon the public mind by would-be expositors, with the result that the period of well-known names drew to a close. The work was fostered, however, by many collective bodies, institutes, workmen's clubs and so on, and, in particular, by the British Association for the Advancement of Science, and the Royal Institution of Great Britain, whose work in this field has been as successful as it has been unremitting.

From its foundation in 1831, one of the principal aims of the British Association was ' to obtain more general attention for the objects of Science'. Its activities, except in time of war, have always centred upon an annual meeting at which are brought together representatives of every department of science excepting that of medicine, a subject with which the Association does not deal owing to an arrangement of many years' standing with the British Medical Association. The Association expressly disclaimed invasion of the ground occupied by other leading scientific societies, of most of which the headquarters, a century ago, were in London. Therefore, the Association has held its general meetings elsewhere than in London, except very rarely ; they were always in other centres of the United Kingdom until 1884, in which year the first overseas meeting was held, in Canada. Since then that Dominion, South Africa and Australia have been visited at irregular intervals, while in 1937 a new and important precedent was created with the dispatch of a strong scientific delegation to India to take part in the jubilee meeting of the Indian Science Congress Association, at whose invitation the delegation was sent.

From an early date the annual meeting of the Association came to be generally regarded as an outstanding scientific event of the year. The presidency of the Association is one of the highest of scientific honours ; the presidential address is a pronouncement which reaches a far wider audience than that which is present in the hall. Down to the outbreak of war, the Press devoted many columns daily to the transactions of the meeting. It was the policy of the Association, particularly during the period between the wars, to include in its voluminous programme each year subjects of broad general interest, whether dealt with in addresses or lectures, or in joint meetings between two or more sections, or in single sections. Moreover, the meetings, commanding the publicity they did, offered occasion for wider interest to emerge in any particular piece of scientific work than it might otherwise have obtained, provided that it appeared to be of general practical or cultural interest. Not a few scientific developments of the first magnitude have been communicated to the world through meetings of the Association.

In 1938 the Association took measures in further recognition of its duty towards the interests of the public. The former annual report was superseded by the publication entitled *The Advancement of Science*, which as soon as conditions permit will appear quarterly, and is intended to deal with the Association's transactions in a manner commanding wider interest than the old annual reports. Further, the Association established a Division for the Social and International Relations of Science, with the power of holding meetings independently of the main body and elsewhere than at the place of the annual meeting. The work of this Division should extend the contacts of the Association with the public : it has, indeed, done so during the war, when the annual meetings have been in abeyance, but the Division has organised a number of conferences on scientific subjects bearing upon the public interest. The Association has recently been consulted by representatives of the Press on the possibilities of strengthening the relations between science and the Press ; the Council has expressed sympathy with

the desire for measures to this end, but has withheld considering action until the outcome of the discussions to which this paper is introductory becomes known. Indeed, it might well be that the Association, with its established position as a mouthpiece of science, might be deemed to be itself the proper vehicle for the conveyance of information to the public by methods suggested in later paragraphs.

The Royal Institution of Great Britain

The Royal Institution of Great Britain has played the part of a pioneer and has occupied a special position. It was founded in 1799 at a meeting held in the house of Sir Joseph Banks, then President of the Royal Society, by a group of scientists and philanthropists. The chief initiative came from Count Rumford (Benjamin Thompson), whose social ideas are to be traced in the statement of the aims of the Institution—' For diffusing the knowledge and facilitating the general introduction of useful mechanical inventions and improvements ; and for teaching, by courses of philosophical lectures and experiments, the application of science to the common purposes of life.' Rumford's experimental kitchens and workshops for the training of artisans, in the premises he had obtained for the Institution in Albemarle Street, fell early into abeyance when he quarrelled with his fellow managers and left the country.

Before his departure, however, Rumford had secured the appointment of a young Cornishman, Humphry Davy, as lecturer in chemistry under Thomas Garnett, the first Professor, and had therewith given to the other side of the Institution's activities a character still preserved as a centre for researches of the highest order, especially in chemistry and physics, and for the regular exposition of new scientific developments to a much wider range of intelligent interests than those of scientific specialists.

Thomas Young was appointed Professor of Natural Philosophy soon afterwards but held the post for only a few years. Davy, on the other hand, became the first of a line of resident Professors for which it would be difficult to find a parallel elsewhere, being followed in direct succession by Faraday, Tyndall, Dewar and W. H. Bragg. It has meant much for the character of the Royal Institution and its special contribution to the national life that every one of these was both a great original investigator and, each in his different manner, a master of the presentation of scientific discovery to the general intelligence by lecture and demonstration.

Apart from this remarkable sequence of its resident Professors, many leaders of British science in their respective departments have held appointments as visiting Professors of the Royal Institution in Physiology, Natural Philosophy and Astronomy ; to mention but a few, we find the names of T. H. Huxley, M. Foster, E. Sharpey-Schäfer, Lord Rayleigh, J. J. Thomson, Ray Lankester, Bateson, Sherrington, Rutherford and Jeans, among those who have so served. All the Professors have given courses of lectures on developments in their own fields of scientific interest and activity. The special Friday Evening Discourses to the Members, begun in 1825, have emphasized rather the part played by science as an aspect of general culture, a proportion of them being given to subjects in the domain of literature and the fine arts. Special mention is also due to the

Christmas courses of ' Lectures adapted to a Juvenile Auditory.' These were started by Faraday in 1826 and, except for the interruption on account of enemy activity in the years 1939–1942, have been given annually. Many famous names are to be found again in the list of those who have given these lectures to children, which have played their own special part in the Royal Institution's contribution to the awakening of a general interest in scientific knowledge.

Science and Society

Until towards the end of the century the material presented to the public was mainly informative, and little attention was given to the social implications of science. With the turn of the century there came a change. The social system that had been the vehicle of science and industry seemed to many inadequate for transporting its burden into the twentieth century. The romantic and optimistic values that had attached themselves to science were harnessed increasingly to criticisms of society. The discoveries of science were utilized by popular expositors not only to inspire enthusiasm for science as such, but to incline the public mind to the view that science was frustrated by an out-moded social order. This period belonged very largely to Mr H. G. Wells.

It is interesting to note in passing that the growth of the belief that science was so shackled led to attempts to transform political economy in itself into a science, namely economics, one of the aims of which was to discover, by mathematical reasoning, whether or not the social system, abstractly conceived, was in logic an obstruction to changes in productive technique resulting from scientific knowledge. The scientific approach to the problem, however, has created a special language by which the popularization of science is still somewhat encumbered.

(3) The phase briefly described above was rudely interrupted by the war of 1914–1918 and by the Russian Revolution. The destruction, suffering and seeming futility of the war, which had brought neither a new world nor any solution of the problems that had beset the old, evoked moods of scepticism and hedonism in the public mind. It was in this atmosphere that certain expositors, especially in the field of physical theory, succeeded in replacing some of the older optimism that had surrounded science in the past by a measure of resignation concerning the inscrutability of first causes. Optimism, at any rate among many people educated in the scholastic tradition, was replaced by a somewhat mystical philosophy.

(4) The fourth period, that in which we now find ourselves, is one in which the dissemination of scientific information has responded to certain important changes both in science itself on the one hand and in society at large on the other.

Secondary education now affects a much larger proportion of the population, and an increasing part of this education is scientific. The popular interest in science is more directly vocational than it was ; people want somehow to be familiar with the development of science, in order to be more successful in their jobs. An ever larger section of the public is engaged in handling products whose emergence from the factory expresses new applications of scientific knowledge. The recent war has put products of applied science into the hands of people who would not otherwise have

been aware of the scientific advances involved. The war and the peace, with mobilization and demobilization respectively, have caused millions of people to change their occupations, to handle products different from those to which they were accustomed. In a majority of such changes the lay mind is made aware of applications of scientific knowledge. The mobility of labour, growing steadily before the war, and greatly stimulated during the past seven years, has increasingly directed the minds of people to the implications, technical and social, of scientific knowledge. It is of importance that this generalization applies no less to the primitive peoples of the Colonies than to the people of Great Britain or of the Dominions and India. In West Africa alone an army of between 300,000 and 400,000 men, mostly tribesmen, found themselves handling modern instruments of war. The impact of this experience upon their minds is a subject suitable for a paper in itself. In short, the market for ' popular science ' has grown in bulk and is very largely vocational in content.

It may be said with accuracy that the public appetite for scientific enlightenment is of a character that goes far beyond the heart searchings about astro-physics and relativity that belonged to the 1920's, and this despite the violence and destructiveness of the recent war. The ordinary man is pessimistic about the fate of humanity, but does not feel that there is any mystery about science.

To cater for the newly awakened popular demand, an immense literature about science has grown up and new popularizers have arisen. The scientific writer has been reinstated among the reading public, but this public is better educated and more concerned with social criticism than in the first period examined above. Films and broadcasts have been made on a multitude of scientific subjects and, indeed, the problem facing us now is not that of finding a way to stimulate a public interest in science, but rather to find means of disseminating scientific information to the public in a way that is accurate, rapid and satisfying. The problem is partly personal and partly administrative.

So far we have considered the changing attitude of the public to science and the reflexion of this attitude in that of the popular expositor to his subject. We must now consider certain changes that have taken place in science itself.

Science, in the first place, has become highly organized. The network of laboratories and research stations covers thousands of workers, from directors, professors and demonstrators to laboratory assistants of many kinds. This implies that he who would expound science to the public is obliged to concern himself not only with the technical subject in question but also with what we may call the civics of science. To divorce the civic organization of science from its subject matter, in order to expound the latter, is to leave the public in ignorance of an important kind of modern knowledge. It is like discussing supply and demand, in economics, without any reference to the existence of the limited liability company, or currency theory without mentioning banks, or the rule of law without discussing the constitution which may or may not embody it. Yet, at the present time the public is less aware of the social organization of science, in its relation to industry, agriculture and medicine, than it is of the mechanism of local and central government. This lack of knowledge is excusable,

since the civics of science are of very recent growth, and the public cannot be blamed for conceiving science in terms of absent-minded professors, whose discoveries emanate from academic cells and laboratory outhouses.

To-day, each field of science, its organization, its personalities and its contemporary problems, are known to very few people outside the intimate circles directly concerned.

At the same time, the work of disseminating news to the public has itself become another civic activity. That is to say, it is carried on through large social organizations, broadcasting systems, film-producing concerns, newspapers, publishing houses, museums, exhibitions, and so on. In brief, science on the one hand and the dissemination of news on the other have each coalesced into distinct social groupings largely unrelated to each other. The recommendation made at the end of this paper is designed to take cognizance of this comparatively recent development.

Parliamentary and Scientific Committee

Before we consider in turn the principal media through which scientific news and information is conveyed to the public, the work of the Parliamentary and Scientific Committee deserves attention.

This body is an unofficial group of members of both Houses of Parliament and representatives of scientific and technical institutions. Its main object is to provide a permanent liaison between scientific bodies and Parliament in Great Britain. It is not in any way an official committee. It is wholly unofficial, self-appointed, self-financed and self-governed, and it relies for its influence and authority on the nature of its membership and the work which it does.

Its present membership amounts to approximately 200 members of both Houses of Parliament and the representatives of some seventy scientific associations and societies. The latter are elected to membership provided that they fulfil one of two tests ; either that they consist mainly of scientific or technical persons, or are concerned mainly with the advancement of some branch of science or technology, but the Committee has absolute discretion to decide in each case whether affiliation would assist the agreed aims and objects of the Committee.

The Committee endeavours to have regular meetings at the House of Commons, which are attended by the parliamentary and non-parliamentary members.

Apart from the general day-to-day work of keeping the scientific bodies informed about parliamentary matters which concern them, and M.P.'s about scientific developments, etc., which have a bearing on legislation, the Committee has endeavoured to use its influence to ensure that effective parliamentary action is taken to advance the cause of science in this country. In this connexion, it has issued certain reports from time to time which have received considerable publicity and which have formed the basis for subsequent action in the House of Commons.

Debates have been initiated on research, deputations have waited upon Ministers, questions have been tabled, and every effort made to ensure that the best interests of science and scientists in this country are not overlooked.

We may now consider some of the special problems affecting the particular media through which scientific information is disseminated to the public.

BROADCASTING

With regard to broadcasting and to the Press, a distinction should be made between the putting out of news and the provision of general scientific matter not of a specially topical character. The news content of Press and broadcasting material creates certain problems common to both, and much of what is said in this section applies also to the Press.

With regard to news proper, that is to say, the announcement of discoveries and the reporting of significant research or controversy, some of the problems in question may be summarized as follows :

(*a*) Who is competent to draft a correct account of the particular piece of scientific news ?

(*b*) How can the news be correctly drafted in time for the news broadcast or to go to press ?

(*c*) Who can come to the microphone, if necessary, at short notice ?

These are largely problems of personnel.

The technical problems of broadcasting scientific matter may be elucidated by the consideration of the following general points.

Normally one of three distinct forms of presentation may be used :

(*a*) *News.* A statement mainly of facts prepared for reception by the ear, as distinct from the eye, for which the Press caters, and in delivery of which the personality of the reader has no material relation with the subject matter.

(*b*) *Talks.* Verbal radio communication in which the speaker normally has a direct relationship with the subject matter. Talks may be for information, comment, instruction or for entertainment, and they may be illustrated by non-verbal sounds, e.g. music.

(*c*) *Features.* A feature programme is normally concerned with one principal theme and makes use of radio-dramatic technique. This entails not only the writing of a script but eventual transmission by radio actors who take the parts of the characters in the production. We may give as an example the story of the discovery of radio-activity, which might be told in radio-dramatic form, the chief characters impersonated being Becquerel, the Curies, Rutherford, etc.

So far as concerns News, (*a*) above, the problem of transmission does not concern us here, since it is the responsibility of professional news-readers already employed by the various radio organizations.

Considering (*b*) and (*c*) above, experience showed at a very early stage that a ' middleman ' was necessary in order that the material for transmission should be capable of reception by the ear to its best advantage. The first requirement in these ' middlemen ' is, of course, a knowledge of radio as a means of communication and particularly an awareness of the differences between material presented for the eye and that presented for reception by the ear without any visual aid.

With Talks there is normally one ' middleman ' only, the ' talks ' producer ; in the case of Features there may be several, namely, the script writer, the producer and, of course, the radio actors, impersonating the characters in the programme.

In defining the term ' talk ' above, the relationship between the speaker and the material transmitted has been stressed, and it is in this relationship that one of the primary functions of broadcasting lies, viz. to enable the public not only to hear an important item of news, comment or speculation, but to hear the voice of the man or woman most competent to express views upon it. This is the best form of authenticity possible for a large audience on a single occasion. In this connexion the function of the producer is two-fold :

(*a*) to ensure as far as possible that particular subjects and particular personalities are made available to the listening public when this is desirable, and

(*b*) to ensure that the detailed make-up of the script fulfils the requirements of the medium.

People unconnected with radio are trained only in writing for the eye, and even experienced lecturers do not necessarily write scripts suitable for broadcasting without advice. The producer is needed to advise on the preparation of the script in the light of his experience, and also to advise on the details of delivery, so that the true personality of the speaker will reach the listener. There are cases when certain disabilities prevent an authority from speaking over the air, no matter how good his material may be. These cases, however, are rare. There are other cases when a man or woman fulfils all the requirements of a first-rate broadcaster with little or no aid from the producer. The majority of people, however, are more or less acceptable, subject to the expenditure of a certain amount of effort by themselves and by the producer.

One of the great crimes in radio is to bore, and there are several ways of doing this :

(*a*) To broadcast subject-matter of no interest to any but an inacceptable proportion of the audience.

(*b*) To present a subject in a way unintelligible to the greater part of the audience.

(*c*) To make sounds that are unpleasing or monotonous. Certain human voices fall into this category.

(*a*) is avoided by selecting subject-matter in the light of the known tastes and background of the radio audience served. (*b*) is avoided by careful editing of the scripts. (*c*) is avoided by not inviting authorities with unfortunate voices to broadcast, but, upon occasion, by getting other voices to read their scripts for them. In some cases voices that are uneasy ' on the air,' or those that are monotonous may be ' diluted,' a second speaker being introduced and the method of question and answer being employed, so that the undesired voice may be heard for short periods only.

Turning to feature programmes, the writing of the script and its production are essentially the business of the radio technician. Nevertheless, if scientific accuracy is to be maintained, authoritative scientific advice is

needed at both stages, particularly in connexion with the writing of scripts.

We have given this statement of the various procedures of broadcasting in order that the scientist may see at what stage his co-operation is needed. In scientific broadcasts up-to-date information and advice is required from the scientist. To get this information and advice is often by no means easy. If 'A' scientists find it almost impossible to keep themselves informed about progress in 'B' sciences, how much more difficult is it for the broadcast producer to keep himself fully informed of progress in all the provinces of science, academic and applied, even if he is himself (as it seems he should be) a qualified scientist.

The needs of the broadcasting service might well be borne in mind by those in charge of any central scientific information service, such as is put forward for consideration at the end of this paper.

The qualifications of the science-talks producer are in fact not so much those of a scientist as of a specialist in the civics of science. He must possess a considerable knowledge of the organized layout of scientific work all over the country, and of the personalities engaged in it. In addition, of course, he must be a good judge of the types of speakers available. A difficulty that faces science-talks producers is often that the individual scientist concerned with a particular piece of news may not be available either for checking broadcast scripts or for making broadcasts at short notice.

There are those who hold that scientists should be less chary of publicity, and that they owe a duty to the public to come forward to the microphone or to some other medium of publicity, at the behest of talks producers and editors, whenever required. The reluctance of many scientists to indulge in publicity is due partly to a healthy apprehension that certain forms of publicity may be conducive to specious workmanship. Certain it is, however, that the organization of science has become hierarchical, that publicity for young scientists tends to be frowned upon by their superiors, and that eminent men are busy already. It is also important in this connexion that publicity for scientific information is often associated with enthusiasm for a social or political cause which, it is hoped, may embrace the more intensive application of science to the betterment of human conditions. Scientists often have personal and philosophical reasons for avoiding the suggestion that they adhere to this or that social philosophy. Moreover, whatever may be the views of eminent men of science, the general public to-day continues to feel optimistic about the improvement of human life under the aegis of science, even though man himself may be regarded as basically incorrigible. For an eminent man of science to broadcast about a new discovery may be to invite him to appear either as an unimaginative conservative in the ears of the public, or as an irresponsible politician in the opinion of his colleagues. In a world somewhat obsessed by ideological considerations, the scientist, like other citizens, is faced with the problem of concealing his enthusiasm from those who are apathetic and his seeming indifference from those who are imbued with enthusiasm. To avoid publicity is a way out of the dilemma. It is a dilemma, however, which lies at the root of the problem of the publicity of science to-day.

With regard to feature talks about science, the problem of getting things done quickly is not so acute. Here the main question seems to be that of the relation between the producer and the speaker. There can be little doubt that it is the producer who must be allowed the final say as to what the public may be expected to understand and what may be beyond its comprehension.

Note on Television

In the presentation of science, as in art, television presents important new opportunities. In the period 1936–1939 many experiments were made in the presentation of scientific material. There were demonstrations of experiments in the studio, the showings of drawings, diagrams, pictures and scientific films, visits to museums, the dramatization of episodes in the history of science, and the appearance before the camera of personalities in the world of science.

Films have already shown how scientific experiments could be telescoped into a short consecutive sequence ; television cameras can do the same job with a heightened sense of actuality and a greater emphasis on the skill and personality of the demonstrator. It is in this sense of immediacy that television demonstrations score. The human element is always present, and although lengthy experiments must be arranged in short coherent sequences, their successful stringing together gains by the personality of the demonstrator.

In the pre-war period well-known scientists collaborated in the demonstration of classic scientific experiments as well as in illustrating their own particular work. For example, Dr C. H. Waddington showed tissue-culture experiments with apparatus brought from the Strangeways Laboratory, Dr Winifred Cullis demonstrated the effect of external and internal stimuli on the action of the heart in human subjects, Professor Waller showed the properties of solid carbon dioxide with their visual effect of creating changing sand patterns. In the same way the application of science to industrial and social problems was demonstrated. Dr Cyril Burt showed how intelligence tests were applied to human material, medical men illustrated the technique of blood transfusion for war purposes, members of the National Institute of Industrial Psychology gave demonstrations of efficient planning and movement in kitchen and workshop.

The development of television will bring a great extension of visits to museums and laboratories, as well as bringing to the screen topical occasions in science and the personalities of scientists from all over the world. There will be much to be learnt about the feature presentation of scientific material, and the dramatization of contemporary scientific history.

FILMS

With films the problems are much less of a personal character than in relation to broadcasting, publishing and the Press. Through the film, publicity is given to the objective content of the film, rather than to the personalities of those concerned in its production.

It is necessary to emphasize that the technical possibilities of the film make it very largely a substitute for direct manual experiment in scientific education itself. Experiments themselves can be filmed, and photographic aids to the illustration of scientific principles are effective.

It is possible that the use of films can assist in bringing education in the methodology of science to many people who, by temperament, are averse to the largely manual techniques of experiment—techniques, it should be noted, that are of value principally as vocational training. At the present time education in science consists of two mutually interacting parts : training in experimental technique and the discipline of scientific knowledge itself. By concentrating on the former, many potentially scientific minds are repelled, through temperamental resistance, from mastering the latter. Advocacy of the use of films is not a plea for the abandonment of training in experimental technique, but rather a claim that films are eminently suitable, either as an addition to experimental work or as an aid to the general education in science of people not destined actually to become practising scientists.

It may be as well to remind ourselves of the very great illustrative power of the film. First, the film can conjure up an image of practically any event that occurs in reality, so that the audience may be vicariously and retrospectively present at the event shown. The film can achieve the same effect for many events which in fact nobody can ' view ' at all. For example, film records can be made by ultra-violet, infra-red or x-ray radiations, showing events which are normally invisible. French astronomers have recorded the sun's prominences in speeded-up motion, using monochromatic light. Thus they have made ' real ' something which it is impossible for the ordinary person to see.

Secondly, as with ordinary photography, the film can use the microscope and the electron microscope, thus introducing people to new ways of thinking appropriate to the microscopic world. The result of using a handkerchief when we sneeze, for example, could be made the subject of a film, whether for students or the general public.

Not only is adjustment of the linear scale possible, but the time scale, also, can be manœuvred, so that phenomena normally thought of in static terms can be presented as dynamic processes. The growth of plants and the development of clouds can be shown in the course of seconds. Conversely, the high-speed camera can render what are normally thought of as instantaneous processes, such as explosions, in a form which shows their course in detail.

Animated diagrams can convey abstract information in a clear yet dramatic form. Colour adds something to the possibilities both of actual and diagrammatic treatment, and stereoscopy will offer new potentialities for expounding three-dimensional spheres of knowledge, such as global geography, astronomy, atomic and molecular physics.

Finally, and perhaps most important, a well-made film can make use of several of these possibilities, presenting aspects of its theme in an integrated fashion. In addition, the work of the research scientist can be shown in relation to industry, and both in terms of their relation to the community. The film, in fact, is perhaps the most powerful instrument for disseminating not only the principles of science, but their social implications.

The Film Audience

The value of the scientific film depends largely on the selection of the audience, and we may now consider some of the lessons that have been learned in this country in this regard.

The organization of audiences for viewing scientific films in Britain is still in an elementary stage, although large numbers of people do in fact see such films. So far, however, there is little information by which we can judge the extent to which the audiences are helped in their search for knowledge.

The popularity of the Ministry of Information ' non-theatrical ' shows of informative films suggests that this field should be developed, e.g. shows to farmers of films on the elements of agricultural science have been very successful. The Information and Broadcasting Department of the Government of India, also, has made films about soil erosion, water supply, and so on, and these are shown to millions of people throughout India.

The most closely knit audiences for viewing scientific films are to be found in the Scientific Film Societies, which now exist in some thirty centres and have an aggregate membership of over 5,000. Such societies normally offer speakers and facilities for discussion, in addition to the showing of films, and they are thus able to exert some influence on the making and showing of scientific films. They are assisted in this work by The Scientific Film Association, whose contacts also include the international field.

The increased interest of the public in science during the war is reflected in an increased tendency for the public cinema to run documentary scientific films, and also films with a scientific reference, such as those of the lives of Edison, Ehrlich and Curie. There is great scope, however, for more intense and responsible efforts in this direction.

Non-theatrical Distribution

If an attempt is to be made to penetrate and extend the non-theatrical market, the distribution organization would have to be fairly elaborate. It would be necessary to establish a ' film library ' from which users could easily obtain copies of the 16 mm. films which they desired.

This library could be organized on the lines of the Central Film Library in Great Britain, where the cost of maintenance or distribution is borne by the Government or the sponsor, thereby allowing borrowers to get their films free save for the return postage. Or it could be organized on the basis of passing on the cost of distribution to the user, as is the case in the Scottish Regional Educational Film Library, where a hire charge is made for the film, which covers the cost of clerical work in booking and invoicing, despatch, wear and tear and replacement. The charge for sound films works out at 5s. a reel for the first day of borrowing and 1s. 6d. for each subsequent day, a figure which bears a relationship to the prices charged by ordinary commercial film libraries.

Distribution methods such as these supply people and places which already own projectors. If, however, there is no projector in the meeting place nor can one be borrowed or hired, the solution lies in the ' Road

Show ' or ' Travelling Unit.' During the war, as is well known, the British Ministry of Information Travelling Units were able to bring to audiences in villages, factories and even in the great cities, special programmes of films to meet their requests or designed for their needs. Naturally the cost of these shows was borne by the Government.

Before the war a number of commercial organizations also ran free road shows at which were shown films sponsored by themselves and the cost was debited to the advertising appropriation. In order to avoid monotonous repetition of a single theme a number of companies sometimes joined together to show their films. In other cases variety was achieved by hiring or borrowing films of more entertaining or sometimes documentary character than straight factual or advertising films. The cost was of the order of 6d. per head.

Finally, there are now signs that a number of firms are prepared to speculate in the provision of film shows of any type or character, the cost at the rate of £8 a day divided among one or more shows to be borne either by the audience or by a sponsoring organization.

It will readily be appreciated that the proper organization of road shows or travelling units needs a small but efficient central office organizing the routeing so as to achieve the maximum efficiency.

The ready-made audiences for the non-theatrical exhibition of films consist not only of groups like the Scientific Film Societies, but also specialist audiences like doctors or nurses, in schools and among university students, in adult educational groups and so forth. Numerically they may not be very large, but the effect of a film programme or ' film meeting,' as explained earlier, is out of all proportion to the size of the audience and for this reason the non-theatrical field should be intensively cultivated if scientific information is to be disseminated within the Empire.

Theatrical Distribution

Theatrical distribution provides a completely different series of problems. The showing of films of a more serious character save in a relatively small number of ' specialist ' cinemas resolves itself into a struggle to break down the belief of the average film exhibitor, for which there is very little evidence, that audiences only go to the cinema for escapist entertainment and that they resent any introduction into the programme of more serious matter.

Opinions vary as to the effects of films shown in commercial cinemas. The feature film obviously compels more attention and is probably more vividly remembered than the short. Hence films like *Pasteur* or *Madame Curie* have a very powerful resultant effect. Production companies however are not very susceptible to outside suggestions when they shape their production policy and programme. The names of well-known stars are regarded by the commercial companies as of greater box-office value than the subject matter of any film in which they may appear.

News Reels

Finally, the news reels offer scope for disseminating scientific news either by means of interviews or by means of special pictorial items. The way

in which the manufacture and use of penicillin has figured in the news reels is an example of this. The organization of such items or shorts may well be a suitable function for the 'institute of scientific information' discussed at the end of this paper.

Finance

It is for consideration whether or not the production and circulation of scientific films deserves special financial provision in the form of a subsidy. Whether this suggestion be adopted or not, it is certain that some assistance other than that provided by market conditions under the present circumstances, would be needed if the use of films for the popular dissemination of scientific knowledge is to be greatly extended in the near future.

Requirements

The development of the film as a means of spreading scientific ways of thought depends on the improvement both of viewing and production facilities. The number and different kinds of sponsors should be increased, and the closest possible collaboration between film makers and scientists is needed. Scientific bodies should conceive it as a part of their functions to encourage the making of good films in their own subjects. The Scientific Film Association exists to foster this view. The film industry should draw for ideas and themes upon the scientific profession, particularly those aspects of it, for example tropical medicine, which have a reference to problems in the colonial countries.

As regards viewing, it is important to ensure that films are made to stimulate discussion, and not to foster a spurious sense of achievement through sitting passively through a 'film show.' Film meetings should be organized by and for the masses of the people. Thus utilized, films can bridge the gap between the low educational birthright of the average man and the high level of awareness which, under favourable conditions, he is prepared to show.

We may add that all schools, universities and meeting places being planned or built, should be provided with suitable apparatus for projecting sound films.

The possibilities for using films for the dissemination of scientific information throughout the Commonwealth, and particularly in India and the Colonies, are immense. It may be that the recommendation made at the end of this paper may have an important bearing upon this aspect of the matter.

MUSEUMS AND EXHIBITIONS

(The Science Museum)

Twenty years ago, Sir Henry Lyons realized that the public knew little or nothing of the large amount of research which was being carried on for the benefit of industry, since the published accounts of it were written in language too technical for them to understand. Consequently there was no means by which the Research Associations and Committees could

inform those who may be interested in such subjects, but who had not sufficient technical or scientific training to read their reports with profit.

It occurred to him that it was well within the province of the Science Museum to arrange for periodical exhibitions at which Research Institutions could bring before visitors to the Museum such interesting results as they have obtained and for which they desire publicity. Such exhibitions he considered would be of real utility, and he reserved one of the galleries of the Museum for the accommodation of exhibits bearing upon the scientific work of Research Associations, or upon the technical operations of the related industries. This experiment proved successful, and up to the outbreak of war over seventy 'Special Exhibitions' had been staged at the Science Museum.

To-day at the conclusion of a second world war the position is modified only in so far as the field of scientific research has been enormously extended, while the general public, having become increasingly conscious of the impact of science on their everyday life, are clamouring for reliable information regarding all branches of scientific research. The gallery at the Science Museum which was reserved by Sir Henry Lyons is still available for the holding of special exhibitions—which will afford public illustration and visual exposition of the current advances in the physical sciences and the application of science to industry—and so to contribute to the better dissemination of scientific knowledge.

Special exhibitions vary widely in their form and purpose, but may be roughly grouped in one or other of the following categories, although in certain cases an exhibition may have claims to more than one group :

(1) purely education	e.g.	exhibition of chinese junks.
(2) historical	,,	centenaries.
(3) research	,,	rubber research exhibition.
(4) industrial or trade	,,	Physical Society's exhibition, plastics industry exhibits.

Of these, groups (3) and (4) aim to present up-to-date scientific news to the public in an acceptable form, and in such a way as to educate the visitor in the principles of the subject, and to give him an idea of modern developments.

A good example of this type of exhibition was one dealing with very low temperatures, and held at the Science Museum in 1936. This exhibition presented a practically continuous programme of interesting demonstrations, and was supported by a series of specialist lectures, each given by a competent expert, while in the case of other exhibitions, a number of interesting films relating to the subject of the exhibition have been shown at frequent intervals throughout the period of the exhibition.

The organization and arrangement of such exhibitions is best undertaken by a small committee, composed of experts in the subject concerned, together with a museum officer who is well versed in the technique of display, and is also familiar with the facilities available in the Museum. Experience has shown that the optimum period for an exhibition of this kind is from one to three months, as anything shorter than one month does not justify the necessary effort, while on the other hand, the attraction

of such an exhibition begins to diminish after three months, and by the end of six months it becomes a normal part of the Museum.

The usual procedure is for the Museum to place a gallery at the disposal of the 'research organization,' which then arranges and finances the exhibition with the exception of warding, the cost of which is normally met by the Museum.

The choice of suitable subjects is unlimited, and includes a large field which would not normally be included in the Museum collections.

Circulation to Provinces

Many years ago the Science Museum possessed a considerable number of 'circulation sets' of scientific and engineering exhibits which were maintained at the Museum and circulated to provincial educational establishments, in a manner analogous to the art collections which are still sent out by the 'circulation department' of the Victoria and Albert Museum. Each science 'set' at that time consisted mainly of a small collection of scientific instruments or of mechanical demonstration models, the circulation of which was discontinued nearly forty years ago. The question of renewing this service has been reopened from time to time, but no satisfactory solution of the problem has yet been produced.

Inquiries have been received regarding the possibility of transferring to the provinces certain 'Special Exhibitions' which have been shown at the Science Museum, but it has only been possible to arrange for this on one occasion, as the primary difficulty, that of cost, has hitherto proved to be an effective barrier. Considerable time and effort is expended in planning, collecting and arranging instructive material for these exhibitions, and the transference of such exhibitions *in toto* to important provincial towns would have a very instructive and stimulating effect, and would be of undoubted interest and benefit to the community in general.

The only available information regarding the cost of circulation was provided by the Rubber Research Exhibition which was exhibited at the Science Museum for six months in 1934–1935. The cost of this exhibition to the Rubber Growers' Association was £1,850 (£1,100 of which was accounted for in salaries), and the exhibition was seen by over 300,000 visitors. It was then packed in three railway containers and taken to Manchester, where it was exhibited for two months and attracted 60,000 visitors. The cost of the Manchester exhibition was £850 (including £470 for salaries and £125 for transport). Finally it was taken to Edinburgh, where it was on view for ten weeks and was visited by 58,000 people. Total cost in this case was £900, which included £600 for salaries and £120 for transport.

In considering these figures it should be pointed out that the Rubber Research Exhibition incorporated a considerable number of demonstration exhibits which required the continual attendance of a staff of technical experts and demonstrators. There is no doubt that most of the special exhibitions could be circulated to three or four different provincial towns at an annual cost of under £1,000.

If, when planning a special exhibition, it were realized at the outset that the entire exhibition might be required for display at several provincial

museums, where facilities for the supply of compressed air, electricity, water and gas might be limited, the exhibits could be designed and constructed accordingly. It may be that in some cases the limitations thus introduced would render the exhibition unsuitable for display elsewhere, but doubtless these cases would be infrequent. In this way it should be possible to build up gradually a series of modern educational and informative exhibitions which would be available for circulation to provincial museums or indeed in exceptional cases to museums throughout the Empire.

In considering the circulation of complete exhibitions, it should be mentioned that similar arrangements are already undertaken for art subjects by the ' Arts Council of Great Britain,' which plans art exhibitions and makes them available *in toto* for display at provincial centres. The Arts Council has arranged a series of six art exhibitions for the current year.

Publications

There is no doubt that many visitors, when visiting even the smallest exhibition, look for some descriptive guide or handbook, giving all the information concerning the exhibition that one should normally require.

The Science Museum has usually proceeded on the assumption that it is its business to provide sufficient notices to explain the general purpose and layout of the exhibition, so that the visitor, if he so desires, can understand the exhibition unaided, and also to furnish a descriptive label with every exhibit, to enable the visitor to acquire the full educational benefit of the exhibition, without having to purchase a catalogue.

Even with all this information freely available, there is a general desire to take away some publication dealing with the exhibition, particularly when the price is not excessive. Recent experience shows that about one in ten of our visitors purchases the guide to the exhibition.

A small and simple booklet, which outlines the purpose and nature of the exhibition, generally suffices for the casual visitor, but a more detailed publication incorporating descriptions of every exhibit is keenly sought after by the more serious visitor. A more elaborate publication, which at the same time tends to become more complicated, is undesirable. The question of advertisements, whether or not they should be admitted, and, if so, their arrangement and number, is one which could be discussed at length, but is best settled on its merits on each occasion.

Conclusions regarding Exhibitions

In the event of an institute for scientific information being set up, it is suggested that this organization would have much useful work to do in connexion with the science museums. These should be asked to co-operate in collecting, collating and distributing scientific information and data, and also in planning, organizing and staging suitable exhibitions, which would help to develop the widest understanding of scientific methods, and a full appreciation of the scientific outlook. Such exhibitions should be made available for display in the provinces ; in certain cases also in Empire countries overseas.

As explained in the section on broadcasting, the problems of the Press and of broadcasting have much in common. Both, more than films or books, are concerned with news proper, in addition to the spread of feature or background knowledge.

At present the severe limitations of space prevent responsible newspapers from providing systematic scientific information services. It should not be forgotten, however, that the primary function of the newspaper is to provide news ; education or instruction is secondary, and will remain so.

A newspaper works against time ; the flow of news, including scientific items, arrives from all parts of the world at all times. Checking is a matter of urgency. If experts are inaccessible or unco-operative, if the news arrives in the middle of the night or close to the time at which the paper goes to press, a responsible editor is obliged to rely on his own scientifically inexpert judgment. If it is interesting, but not of great moment, he will discard or defer the item, but if it appears important even the most reputable editor must take a risk and publish. Moreover, even a qualified scientific correspondent or consultant will find it difficult, from time to time, to pass judgment on a new discovery or pronouncement without a ' second opinion ' from a further authority.

We have discussed above the difficulties of scientists in regard to publicity. As a counter charge to the alleged irresponsibility of some newspapers, many newspapermen would say that certain scientists are burdened with an excessive responsibility, amounting upon occasion to priggishness. Mutual distrust, however, can be dissolved only by common understanding, and, we suggest, by a working arrangement between journalists and scientists. Indeed, only some such arrangement can give protection to scientists against misrepresentation in the Press, or against the charge that they are looking for publicity.

The present sources of scientific news and material are (1) scientific publications, (2) meetings of learned societies, (3) public conferences and lectures, (4) official announcements, (5) technical journals, (6) laboratory and common-room gossip.

These provide the clues which the Press and periodicals follow up with varying degrees of accuracy and responsibility. The source materials themselves present difficulties :

(1) Scientific publications. These, to quote Sir Henry Dale, have developed a ' slang ' often unintelligible even to experts, more so to experts outside a limited field, and completely so to the layman.

(2) Learned societies. The same difficulty, so far as the Pressman is concerned, applies to these, with the added difficulty that no newspaper or news agency can afford to assign staff to attend many meetings of these societies on the off chance that ' there may be something in it.'

(3) Public conferences and lectures. Usually speakers provide summaries, cautious and indigestible briefs, of what they propose to say. When the Press discards these and seizes upon a colourful statement, or hardens a ' perhaps ' into a positive pronouncement or claim, the scientist regards it as a betrayal and his distrust of the

Press is correspondingly increased. Similarly, if he provides a full paper he is resentful when his careful arguments, often with good reason, are condensed, or if passages are taken out of their context, or if he finds himself head-lined.

(4) Official announcements. These are usually government or commercial announcements. Press releases by government departments, notably the D.S.I.R., have become common and they are comprehensible and intelligible accounts of scientific discoveries or processes. Commercial announcements are usually ' good stories,' as they are meant to be. They are suspect as publicity or special pleading, but if they come from a reputable source they may be reliable.

(5) Technical journals. These are valuable as predigested material, dealing usually with the application of scientific information and often not beyond the general reader. Without doubt the popular Press would be well advised to make use of the assistance of the technical Press in dealing with day-to-day problems. The editors of these journals can usually supply answers to questions regarding the application of scientific knowledge to industry, or give information about the authorities who should be consulted in special cases.

(6) Laboratory and common-room gossip. This cannot be disregarded as a source but is unreliable and dangerous, for it usually refers to incomplete and unconfirmed experiments, or useful lines of inquiry which may be presented irresponsibly as new discoveries.

The establishment of a proper science information service has been discussed at various times during the past twenty years. Such a service exists in the United States where ' Science Service,' an institution for the popularization of science, was established in 1921, with an endowment from the Scripps Trust. It is non-profit making and the trustees are nominated by the American Association for the Advancement of Science, the National Academy, the National Research Council, the journalistic profession and the Scripps Trust. It issues a weekly Science News Letter and provides a syndication service for newspapers and magazines.

It has to be recognized in Britain, however, that such a service would have to be heavily endowed. In contrast to those of the United States, British newspapers are concentrated in national dailies, whilst the circulations of the provincial papers are of necessity comparatively small. National dailies, being highly competitive, object to being spoon fed with the same material as their rivals ; they want their ' exclusives.'

Something might be done within journalism itself if the popular Press would be prepared, under difficulties, to turn to the technical journals for advice and guidance, as well as for material, for the technical Press serves a critical and informed public and is therefore highly responsible.

Another means of ensuring accuracy and greater responsibility in popular scientific news would be for a group of scientific bodies, or for the British Association to form a panel of experts, forming a cross-section of science, which could be consulted. It would mean the establishment of a reference bureau with a staff.

A more ambitious proposal for dealing with the difficulties of the Press could also deal with those discussed above in connexion with other media. This proposal is examined in our recommendations, which are set out below.

CONCLUSIONS AND RECOMMENDATIONS

In the above brief survey of some of the media through which scientific information is disseminated to the general public, we have emphasized certain points, which we may now bring together.

(1) Scientific research is carried on by many thousands of specialists, working in an elaborate network of organizations.

(2) The specialization of science itself and the complexity of its civic organization are baffling to the public.

(3) The social hierarchy that has grown up among scientists in a world of conflicting values is responsible for a certain caution and conservatism about publicity.

(4) The media for disseminating news and information, whether scientific or not, have also become socially elaborate.

(5) The mobility of labour before, during and after the war has greatly stimulated the public interest in science, an interest that is philosophically optimistic and largely vocational.

In the light of the considerations argued above, certain needs are becoming apparent. These needs are personal on the one hand and administrative on the other.

The present situation would seem to provide scope for a new kind of popular expositor. Just as the elaborate civic organization of science calls for the administrator who is not *prima facie* a practising scientist but yet who understands sufficient about science to enable him to administer large or small organizations, so the dissemination of scientific information to the public calls for a publicist of a new kind.

The art of the scientific publicist should consist of two faculties : (*a*) fluency in knowledge of the existing social organization of science and (*b*) ability to grasp sufficient of a particular specialism to be able to make a story of informative value to the general public.

Under (*b*) would come those who are masters either of the written or the spoken word, and under (*a*) persons able to refer scientific stories to the proper expert authorities without delay.

It is for consideration that, just as the professional administrator should perform the valuable function of liberating the practising scientist from the hampering responsibility of administration, so the professional scientific publicist should act as a link between the public and the man of science. Such a link would, of course, not preclude but encourage direct contacts between the scientist and the public. Indeed, since scientists are citizens also, it is reasonable that they should speak and write for the public as much as they choose. The proposed scientific publicist would, however, take from the shoulders of the scientist much of the responsibility for public enlightenment that is now of a routine character.

On the administrative side it would seem that there is scope for an organized but not exclusive channel of contact between agencies responsible for the dissemination of scientific information and the original sources of scientific knowledge. What is needed, in short, is an *Institute of Scientific Information*. Some suggested functions of such an organization may be summarized as follows :

(*a*) It would maintain, in a readily available form, a record of all scientific research in Great Britain, in the Commonwealth and in the world as a whole. Such information, together with the names of the scientists involved, would be kept in a tabular form, and it would be a part of the daily work of the Institute to keep such records up to date.*

It is noteworthy that there is no learned body or authority in this country to which any journalist or other inquirer may go to discover either the location of scientists or the kinds of research in progress in each field.

(*b*) The officials of the Institute would be in telephonic or other communication with scientists in every field. It would be their job to find ways and means of obtaining access to scientists with a view (*a*) to securing the latest information in a form suitable for issue to the Press or the B.B.C. and (*b*) to refer to the proper scientific authority any scientific story brought to them by the Press, the B.B.C., etc.

(*c*) It would supply to the Press and other media complete lists of learned points in pure science, and of technical points in applied science. It would guide Pressmen and others in their search for authorities on all scientific subjects.

(*d*) The Institute would be responsible for keeping the Press and the B.B.C. supplied with a stream of official news releases about scientific matters of interest, whether in the pure or in the applied fields. Such releases, bearing the imprimatur of the Institute, would carry special authority with the Press, and would do much to discourage fantastic stories and sensationalism, in advance. They would also discourage charlatanism and pseudo-scientific claims to which uninstructed sections of the public are at present widely exposed.

(*e*) Officials of the Institute would be available to advise and recommend on all matters connected with the publicity of science. The producers of scientific films, organizers of broadcasts, planners of exhibitions, local authorities seeking to start exhibitions or museums, etc., all would look to the Institute to help them with advice and active co-operation.

These would be some of the main functions of the suggested Institute. It is proposed that it should be endowed partly from public and partly from independent sources, and that it should be allowed a large measure of freedom to present scientific information to the public in controversial guises. The Institute would be called upon to issue pronouncements upon extremely controversial issues, and it is unlikely that matters affecting such social studies as anthropology, economics or ethnology, etc., could be excluded from its scope. Any such exclusion would discredit the Institute, in the eyes of the public, as a pillar of conservative values, from the outset. Like the B.B.C. the Institute would, and should, draw upon itself both criticism and praise. Indeed, the vitality of the Institute would turn upon the sincerity with which it reacted to the varying interpretations of the social function of science.

It is suggested that the desirability of the proposed Institute should be

* The staff of the Information Bureau available to delegates of this Conference were put to several months of work, in letter-writing alone, in order to prepare the list of researches now available to them. An examination of the list will indicate the kind of record that might be maintained by the proposed Institute.

discussed at this session. If the general proposal is accepted, then other matters for discussion would be :

1. Method of financing :
   (*a*) Government grants,
   (*b*) Endowments.
2. Authority to whom it should be responsible.
3. Scope and coverage.
4. Relations with UNESCO.
5. Relations with science and its popular dissemination in the various parts of the Commonwealth, India and the Colonies.
6. Additional functions, e.g. publication of a journal or journals.

It should be emphasized that it is not proposed to set up any organization whose functions would overlap with those of an existing one having the same aims. It may well be that no better parent organization for the Institute could be suggested than the British Association for the Advancement of Science, whose work in this field has been famous for more than a century.

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